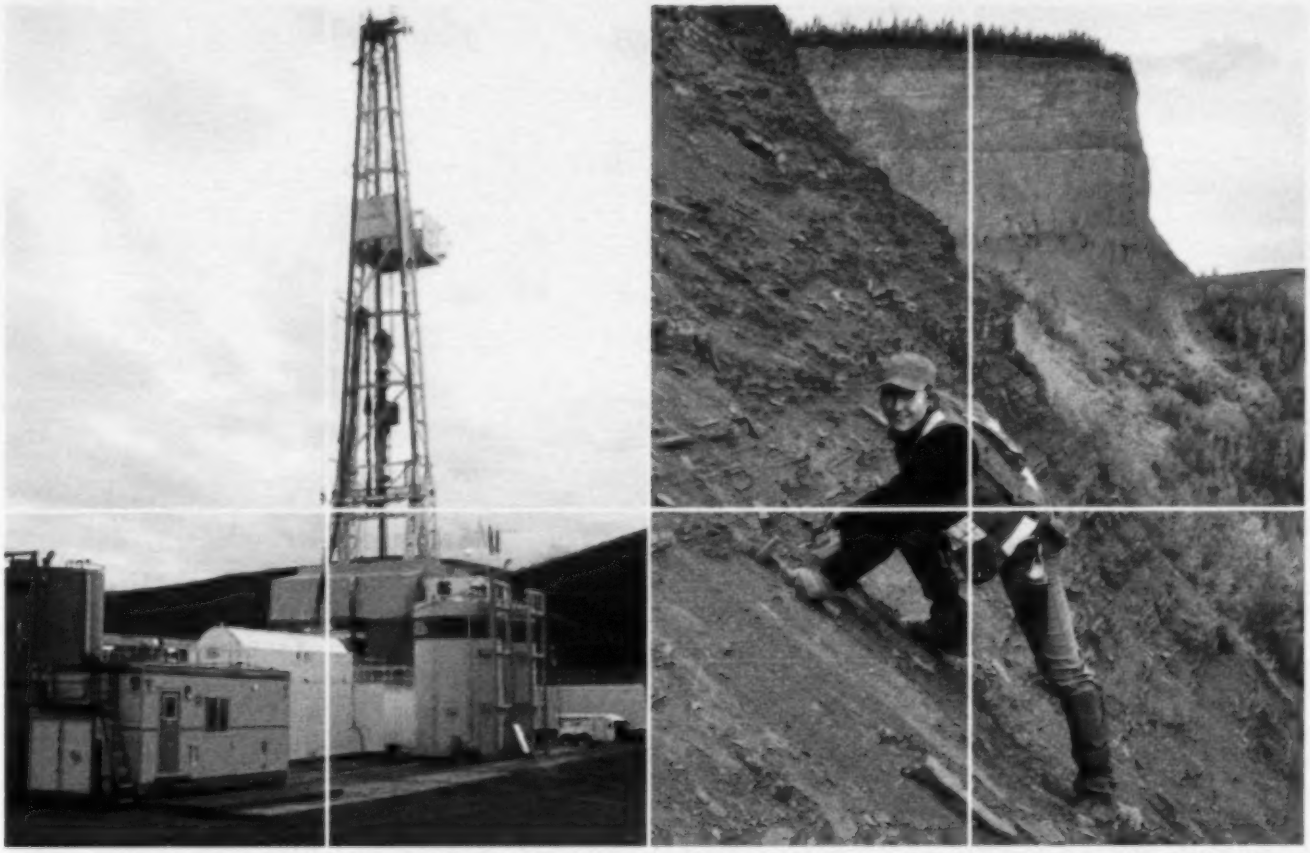
Summary of Shale Gas Activity in Northeast British Columbia 2013

OIL AND GAS REPORTS 2014-1



Oil and Gas Division
Tenure and Geoscience Branch

BRITISH COLUMBIA

Ministry of
Natural Gas Development

© British Columbia Ministry of Natural Gas Development
Tenure and Geoscience Branch
Victoria, British Columbia, September 2014

Please use the following citation format when quoting or reproducing parts of this document:

Adams, C. (2014): Summary of shale gas activity in Northeast British Columbia 2013; *in* Oil and Gas Reports 2014, *British Columbia Ministry of Natural Gas Development*, pages 1–23.

Colour digital copies of this publication in Adobe Acrobat PDF format are available, free of charge, from the Business–Natural Resource Industries section of the Government of British Columbia home page website at: *http://www2.gov.bc.ca/industryactivity*

TABLE OF CONTENTS

INTRODUCTION 1

BACKGROUND 2

DATA SOURCES 3

SHALE GAS EXPLORATION ACTIVITY 3

Horn River Basin 4

Land Sale Activity *4*

Industry activity *4*

Production *7*

Liard Basin 7

Land Sale Activity *7*

Industry Activity *8*

Cordova Embayment 10

Land Sale Activity *10*

Industry Activity *10*

Production *11*

Bivouac-Muskwa 11

Land Sale Activity *11*

Industry Activity *11*

Production *12*

Montney Play Trend 12

Land Sale Activity *12*

Industry Activity *13*

Production *20*

Cretaceous Shale Gas Activity (Fort St. John and Northern Foothills Regions) 20

Industry Activity *20*

OUTLOOK 20

ACKNOWLEDGMENTS 21

REFERENCES 21

SUMMARY OF SHALE GAS ACTIVITY IN NORTHEAST BRITISH COLUMBIA 2013

British Columbia Ministry of Natural Gas Development
Tenure and Geoscience Branch
Christopher Adams, ASc.T, Oil and Gas Specialist[1]

ABSTRACT

Shale gas prospects in Northeast British Columbia continued to be the focus of industry in 2013 with most land sale and drilling activity occurring in the Montney play trend. Bonus payments from the sale of Crown petroleum and natural gas rights reached a total of $225 million in 2013, the second lowest total since 1999 but a 56% increase from 2012. Almost 98% of the 2013 bonus total—a slight increase from the 87% share in 2012—was directed toward the exploration and development of British Columbia's shale gas regions. Operators continue to focus on the evaluation and extraction of these world-class shale gas resources, which have the potential to hold more than 400 trillion cubic feet of marketable natural gas. Recoverable resource estimates for these regions continue to improve as progress is made with horizontal drilling techniques and hydraulic fracturing procedures. The four major shale gas regions in Northeast British Columbia—the Horn River Basin, the Liard Basin, the Cordova Embayment and the Montney play regions—continue to add substantially to Western Canada's natural gas supply base. Operators in these regions have shown remarkable flexibility in being able to respond to the recent upswing in natural gas prices and to the ongoing development of an overseas natural gas export industry. In terms of industry drilling activities, Northeast British Columbia's Montney play region is the prize resource play in the Western Canada Sedimentary Basin (WCSB), and it continues to have a significant advantage over other shale gas regions in the province because of its liquids-rich gas component. Production from the region is now approaching a calendar average rate of 2.3 billion cubic feet per day.

This report highlights shale gas activity in the key shale gas regions of Northeast British Columbia with most of the statistics presented focusing on 2013 and early 2014.

Adams, C. (2014): Summary of shale gas activity in Northeast British Columbia 2013; *British Columbia Ministry of Natural Gas Development*, 23 pages.

[1]British Columbia Ministry of Natural Gas Development, Tenure and Geoscience Branch, Victoria, British Columbia, Canada; email: Christopher.Adams@gov.bc.ca

Keywords: shale gas, exploration and development, industry activity, Northeast British Columbia, petroleum and natural gas rights, resource region, drilling, rig releases, operators, producers, special projects, horizontal drilling, hydraulic fracturing, natural gas, natural gas liquids, liquefied natural gas, Horn River Basin, Cordova Embayment, Montney play region, Liard Basin, production, reserves.

INTRODUCTION

Northeast British Columbia's growing shale gas production continues to generate new opportunities for the export of natural gas to overseas markets. Almost 90% of wells drilled in British Columbia are now targeting unconventional gas, with British Columbia's world-class shale gas plays, such as the Horn River Basin, the Cordova Embayment, the Liard Basin and the Montney play trend, at the forefront of this activity. Not only have these shale gas regions had a major impact on the strategy to supply natural gas to Pacific Rim markets, they have also challenged oil and gas operators to further develop natural gas extraction techniques using optimal well and completion design techniques for horizontal drilling, multistage fracturing and practical advances in water usage. As producing companies continue to see notable success in their shale gas development progress, they continue to make significant purchases of petroleum and natural gas rights, particularly in the northwestward sections of the main Montney fairway. In 2013, Northeast British Columbia's shale gas regions garnered almost 98% of the provincial land sale bonus total of $224.7 million. This was a slight increase from 2012 when provincial land sale auctions tallied more than $139 million in successful bonus bids with shale gas–directed activity accounting for almost 87% of the bids. The Montney play trend, which generates considerable natural gas liquids (NGLs) and condensate volumes, accounted for almost the entire 2013 bonus total. The Liard Basin saw a small allocation of the bonus total, whereas the Horn River Basin and Cordova Embayment did not see any successful bids for parcels.

During the last decade, the British Columbia Oil and Gas Commission (OGC) approved more than 30 innovative technology (formerly known as experimental) projects for evaluating the shale gas potential in Northeast British Columbia. Innovative technology applications, analyzed by the OGC, can be approved as a Special Project Order under Section 75 of the *Oil and Gas Activities Act*. Orders are subject to specific detailed conditions, which include the submission of an annual progress report to the OGC. Innovative technology projects are designated as such if there is an application of innovative technology or if there is an innovative method of carrying out oil and gas and related activities. To date, most innovative technology projects approved for shale gas potential in Northeast British Columbia have been in relatively low-density drilling areas such as the Horn River Basin; however, some schemes have been approved for fields such as Altares, Farrell Creek, Pocketknife and Town in the northwest extension of the Montney play trend. In the Horn River Basin, innovative technology project requests are being denied more often because the proposed development technology is no longer considered unique to many areas of the basin.

BACKGROUND

The number of wells drilled in British Columbia since the early 1900s will reach 24 000 before the end of 2014 (Fig. 1); however, it was not until the 1950s that petroleum exploration and development began in earnest in British Columbia. The northeast portion of British Columbia, which is part of the Western Canada Sedimentary Basin, is the only area of the province currently producing commercial quantities of oil and natural gas. Historically, drilling and production activity for oil and natural gas focused on the shallower Cretaceous and Triassic reservoirs in the Fort St. John region and the shallower depths of the larger mid-Devonian gas pools in the Northern Plains region. In the 1990s, natural gas producers began focusing on tight gas development of the regionally extensive Devonian shelf carbonates of the Jean Marie platform and the shelf-edge play in the Fort Nelson resource region. In 2003, industry began ramping up activity on tight gas development in basin-centered resource plays such as the Cretaceous Cadomin in the Deep Basin region. With advances in horizontal drilling and hydraulic fracturing techniques, producers are now unlocking vast tracts of gas-bearing shales in the Horn River Basin, Cordova Embayment, Liard Basin and the Montney play trend (Figs. 2, 3).

Prospective shale gas formations in the British Columbia portion of the Western Canada Sedimentary Basin potentially contain large volumes of hydrocarbons (Table 1). Organic-rich shales can generate and store methane due to biogenic gas generation during the early diagenesis stage and subsequent catagenic generation at higher levels of maturity. Most shales have low matrix permeabilities and require extensive and widespread natural or induced fracture systems to sustain commercial flow rates. Although there has been much publicity regarding the success of several shale gas plays in the United States, British Columbia's shales are recognized as having large-scale potential for with more than 400 trillion cubic feet (Tcf) of ultimate marketable gas. In 2011, an energy market assessment by the British Columbia Ministry of Energy and Mines and the National Energy Board estimated a medium case, ultimate gas-in-place of 448 Tcf in the Horn River Basin and an expected marketable resource estimate of 78 Tcf. The assessment centered on the Upper and Middle Devonian basinal shales of the Evie (Klua), Otter Park and Muskwa members of the Horn River Formation and accounted for drilling to year-end 2010 (British Columbia Ministry of Energy and Mines and National Energy Board, 2011). On November 6, 2013, the National Energy Board, the OGC, the Alberta Energy Regulator and the British Columbia Ministry of Natural Gas Development jointly released the first study ever to estimate the marketable unconventional petroleum resource in the Montney Formation, which is considered one of the largest gas resources in the world. That study

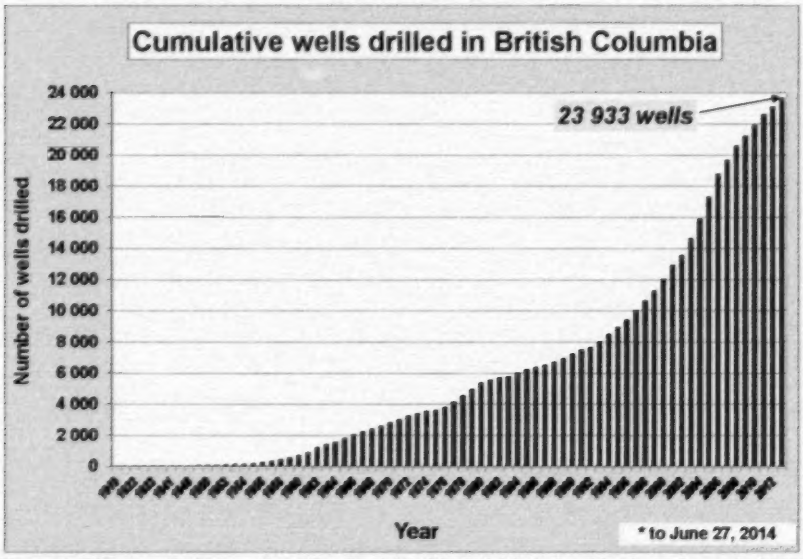


Figure 1. The cumulative number of wells drilled in British Columbia since the early 1900s will surpass 24 000 in 2014. Most wells drilled prior to 1920 were located in more accessible regions of the province such as the Fraser Delta in the southwest. In 1921, the first four exploration wells were drilled in the Peace River area of Northeast British Columbia. The wells were part of a test-hole program operated by the provincial government (Janicki, 2008).

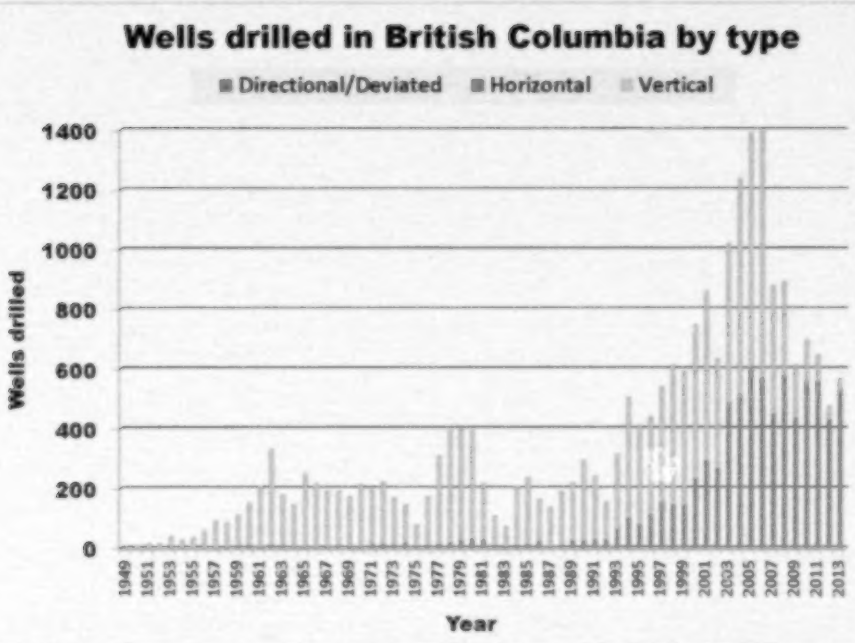


Figure 2. The annual number of horizontal wells drilled in British Columbia began reaching double digits in 1993, accounting for approximately 10% of all wells drilled. Today, more than 92% of all wells drilled are horizontal.

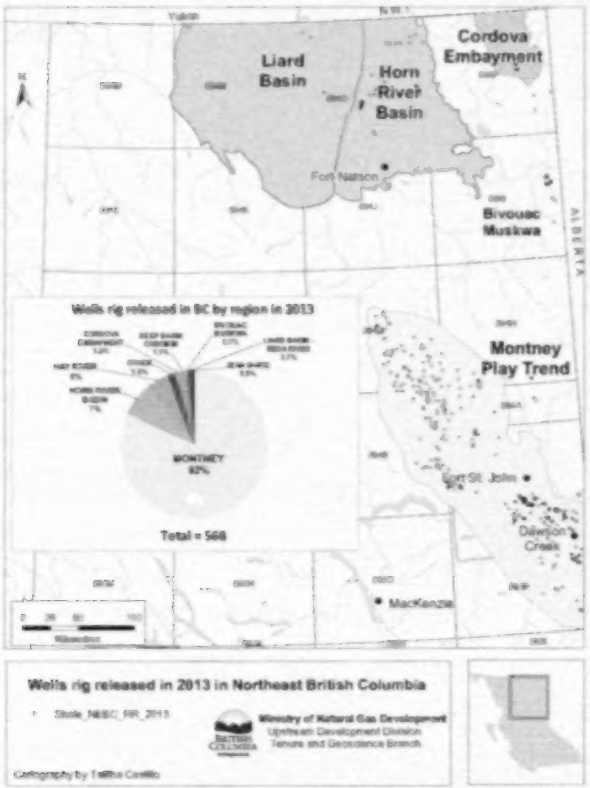


Figure 3. A total of 568 wells were rig released in Northeast British Columbia in 2013. Of those, 411 wells have been given a gas well status. Most wells are now drilled in the province's unconventional gas regions.

estimated that the British Columbia portion of the Montney petroleum resource is expected to contain 271 Tcf of marketable natural gas. Further assessments to determine the technically recoverable and marketable resource potential of the Cordova Embayment and the Liard Basin in British Columbia are ongoing. Numerous stratigraphic horizons and play areas in Northeast British Columbia have exceptional potential for containing unconventional resources and only a relatively small portion has been commercially produced thus far.

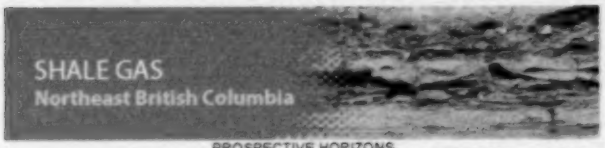
DATA SOURCES

Data for this report have been collected from available public sources. No confidential data or information has been used in its preparation and all results are based on information available at the time of the review. For ease of analyses and description, the key shale gas regions in Northeast British Columbia are displayed in Figure 4. Shale gas activity within the vast region of the Liard Basin (upper left in Fig. 4) is currently taking place within the central and northern areas of the outline shown. The Horn River Basin, north of the town of Fort Nelson, and the Cordova Embayment to the east, are bordered by a Middle Devonian carbonate platform succession. Further south, the Montney play trend now encompasses approximately 2.9 million ha from the south Peace region near the city of Dawson Creek extending up to the Tommy Lakes and Trutch areas in NTS map area 094G/10.

SHALE GAS EXPLORATION ACTIVITY

Bonuses collected from the sale of British Columbia's Crown petroleum and natural gas (PNG) rights in 2013 totalled $224.7 million, up 61% from the previous year. Of that total, $219.2 million, or 97.5%, was directly attributed to interest in Northeast British Columbia's shale gas plays (Fig. 5). Almost the entire percentage was directly related to shale gas development in the Montney play region and a small portion was accredited to the Liard Basin and to the Muskwa play area at Bivouac.

TABLE 1. PROSPECTIVE HORIZONS FOR SHALE GAS IN NORTHEAST BRITISH COLUMBIA.



PROSPECTIVE HORIZONS

	Formations	Description	Depth	Average thickness	Total organic carbon	Gas in place
LOWER CRETACEOUS	Wilrich and Buckinghorse shales	Potential interbedded sand and siltstone	600–1200 m	100 m	2.3%	60 Bcf per section
JURASSIC	Nordegg and Fernie shales	Recognized source rocks	1200–2500 m	Up to 30 m organic-rich section	up to 14%	>20 Bcf per section
TRIASSIC	Doig, Doig Phosphate and Montney	Montney turbidites may increase permeability. Phosphate units have high TOC and are excellent source rocks.	1200–3000 m	300–500 m	0.5 to >10%	10–110 Bcf per section
DEVONIAN	Exshaw Besa River Fort Simpson Horn River and Muskwa	Exshaw and Muskwa are widely distributed organic shales. Fort Simpson and Besa River are thick basin-filling shales.	1600–3500 m	Huge thicknesses are common with some high TOC intervals.	0.5 to >10%	10–100 Bcf per section

GEOLOGICAL ANALOGUE

MISSISSIPPIAN	Barnett Shale (Fort Worth Basin)	Marine-shelf deposit	2000–2500 m	100 m	4.5%	140 Bcf per section

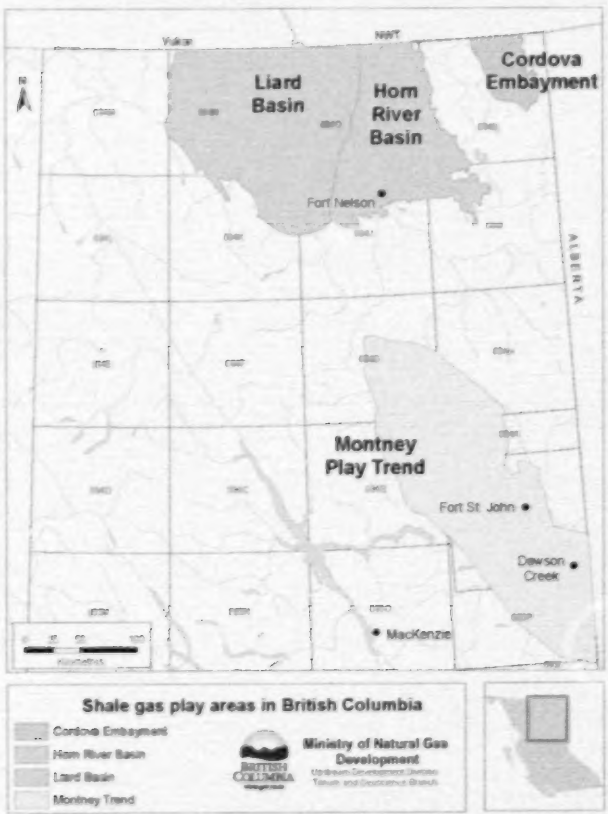


Figure 4. Key shale gas regions of Northeast British Columbia.

Horn River Basin

The Horn River Basin covers an area of approximately 1.15 million ha within the Fort Nelson–Northern Plains region. It lies east of the Bovie Lake–Maxhamish fault system and extends east and south to the Devonian Slave Point barrier reef complex (Fig. 6). Prior to recent shale gas interest, approximately 300 wells had been drilled in the basin, mainly targeting carbonate plays of the Mississippian Debolt Formation and the Middle Devonian Keg River and Pine Point formations. During the last eight years, major and intermediate producers approved for innovative technology projects or experimental schemes have been testing potential reservoirs in the Upper Devonian to Lower Mississippian Exshaw shale and the Muskwa–Otter Park members of the Middle Devonian Horn River Basin. These producers have been extremely successful in unlocking the potential of these organic-rich shales, which has resulted in established production from the area.

Land Sale Activity

There were no PNG rights sold within the Horn River Basin in 2013, marking the first time since 1999 that no annual bonuses were collected within the Horn River Basin. Only one parcel was purchased in 2012 by Standard Land Company at the February PNG rights disposition. The land broker picked up a 269 ha lease at the southern tip of the Horn River Basin in NTS 094J/09 for $23 330. Rights purchased were below the base of the Upper Devonian Fort Simpson zone but excluded natural gas in the Middle Devonian Slave Point zone. This drought of land sale activity comes only five years after a record bonus total of $1.1 billion was achieved in 2008. It indicates that producers are now conducting their drilling programs on previously purchased lands (Fig. 7).

Industry activity

Nexen Energy ULC is listed as the second busiest the operator in terms of shale gas–directed wells drilled since 2005 (Fig. 8). Northeast British Columbia is an important investment destination for **CNOOC Limited** (China National Offshore Oil Corp.) following its acquisition of Nexen Inc. in 2012. **Nexen Energy ULC** was the busiest operator in the Horn River Basin in 2013, drilling all 20 if its shale gas–directed wells in the **Komie** area (NTS 094O/01). The producer has access to one of the highest quality reservoir portions in the basin and, in most cases, has secured tenure until 2018 on the majority of its 60% working interest lands in the Komie area. In August 2012, Nexen closed a joint venture agreement to create a strategic partnership with **INPEX Gas British**

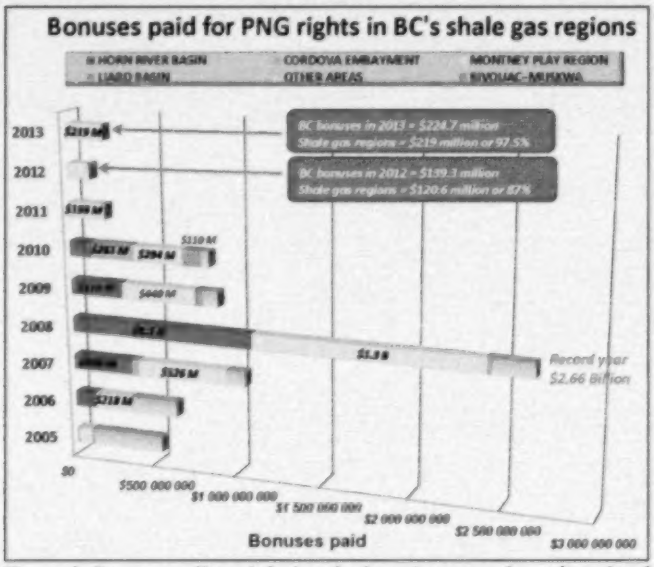


Figure 5. Bonuses collected during the last nine years from the sale of Crown petroleum and natural gas (PNG) rights in British Columbia's shale gas regions. Since 2011, land brokers and producers have focused on purchasing PNG rights in the Montney play region. For the second year in a row, there were no successful bids for PNG rights in the Horn River Basin. The Cordova Embayment has not seen PNG rights sold since 2010.

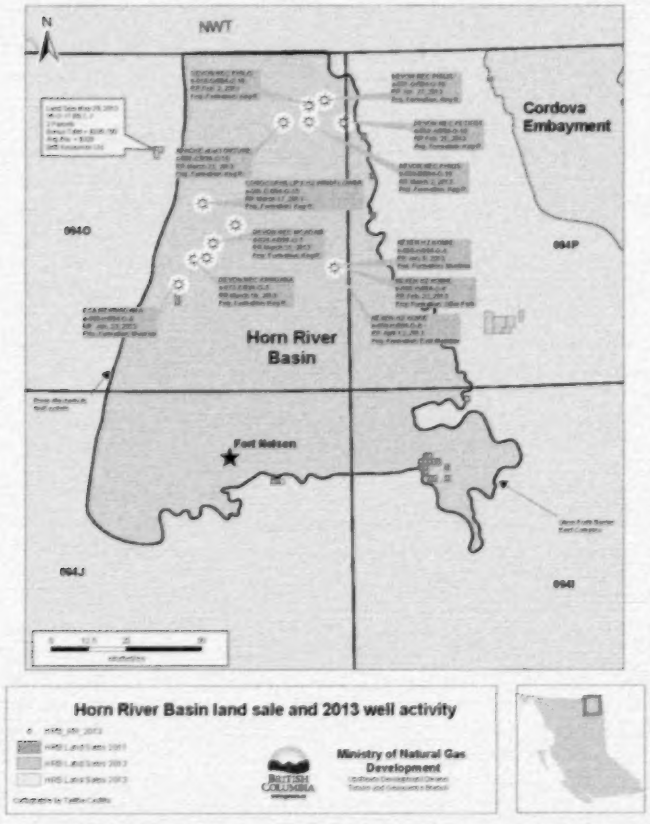


Figure 6. Horn River Basin rig releases in 2013 and areas of land sale activity from 2011 to 2013. Abbreviation: avg, average; R, river; RR, rig released.

Columbia Ltd. (IGBC), a consortium led by Japanese oil and natural gas producers to develop shale gas in the Horn River Basin, the Cordova Embayment and the Liard Basin (Nexen Inc., 2012). The agreement is a significant part of Nexen's shale gas strategy in Northeast British Columbia because it makes substantial upstream expertise available and offers a joint effort in studying the feasibility of potential downstream projects and the export of liquefied natural gas (LNG). In fact, Aurora Liquefied Natural Gas Ltd., a corporation jointly owned by Nexen Energy ULC, **INPEX Corporation** and **JGC Exploration Canada Ltd.**, recently applied to the National Energy Board for a licence to export LNG from a proposed LNG plant near the Prince Rupert area for a 25 year term (National Energy Board, 2013). Nexen and IGBC hold approximately 121 000 ha in the Horn River Basin, Liard Basin and the Cordova Embayment.

Encana Corporation finished drilling operations on 11 wells in the Horn River Basin in 2013; all were drilled in the **Kiwigana** area (western part of the Horn River Basin). Thirty wells have been drilled by Encana in this area since 2011. The first gas production occurred in 2012 from 16 wells with another four coming on stream in 2013. Production rates from the area's four producing wells in 2013 were between 2.9 and 4.7 million cubic feet (mmcf) per calendar day (November 2013 rates). Encana has an extended farm-out agreement with **Korea Gas Corporation** to invest $185 million on approximately 8100 ha (20 000 a) in the Horn River Basin. Encana did not drill any wells in its core area of **Two Island Lake** in 2013, underscoring the slower overall drilling activity levels in the Horn River Basin as a result of low natural gas prices and the lack of natural gas liquids (NGLs) throughout the entire basin. In November 2013, Encana's average calendar daily gas rate from 62 shale gas–producing wells in the Horn River Basin was approximately 189 mmcf/d. Cumulative production from April 2007 to the end of November 2013 was approximately 219 billion cubic feet (Bcf). Encana holds approximately 90 000 net ha in Horn River Basin and is listed as operator for 88 shale gas–directed wells rig released since 2006 (Fig. 8).

Devon Canada Corp. continues to maintain a firm position in the Horn River Basin, despite recent announcements regarding North American portfolio repositioning and the divestiture of its Canadian conventional oil and natural gas assets (Nickle's Daily Oil Bulletin, 2013a). Since 2005, Devon has drilled more than 30 wells in the basin, mainly in the **Komie**, **Petitot River** and **Tattoo** areas.

For the time being, the divesture announcements do not include assets in the Horn River Basin. Drilling in 2013 consisted of eight vertical wells rig released during the first three months of the year. Four wells were drilled in and around the Kiwigana area and the remaining four were drilled further north near the Petitot River area. All wells listed a projected target in the Middle Devonian Keg River. Devon will continue to conduct minimal drilling in the Horn River Basin to hold its acreage. The producer holds more than 70 000 net ha with the potential to produce up to 700 mmcf/d from more than 1500 risked locations (Devon Energy Corporation, 2012).

Quicksilver Resources Inc. continued to manage commitments with its successful horizontal well program in the Horn River Basin's **Fortune** area. Although minimal drilling activity was planned for 2013, the producer managed to complete operations on three groundwater source wells in the area in late 2013. Water source wells are drilled to reduce the reliance on surface water for hydraulic fracturing requirements and to supplement water requirements with various sources of nonpotable groundwater. These shallow wells are drilled into Quaternary-aged sediments and are usually completed within a sandstone bedrock aquifer of less than 200 m depth or in a shallow sand and gravel aquifer within glacial drift with expected depths of 100 m or less. Quicksilver's horizontal wells in the Fortune area have been targeting shale gas in the Devonian-aged Muskwa and Klua formations. The producer has acreage in the area totalling 52 250 ha (129 109 net acres) with an unbooked reserve potential of 14 Tcf (Quicksilver Resources, 2014). In the third quarter of 2013, average net production was 56 mmcf/d from 12 producing wells. Quicksilver has acquired discounted treating capacity on an interim and interruptible basis at an existing gas plant in the Horn River Basin. This arrangement will continue until a third-party plant, in which Quicksilver has firm capacity, is commissioned. In October 2013, Quicksilver was issued an environmental assessment certificate from the British Columbia government for a proposed $760 million Fortune Creek natural gas project in the Horn River Basin (British Columbia Newsroom, 2013). The Fortune Creek project will be developed 110 km north of Fort Nelson and will be constructed in three phases with an initial capacity of 150 mmcf/d, later increasing to 600 mmcf/d (Nickle's Daily Oil Bulletin, 2014a). Quicksilver is also negotiating with select joint venture partners for an integrated Horn River Basin project.

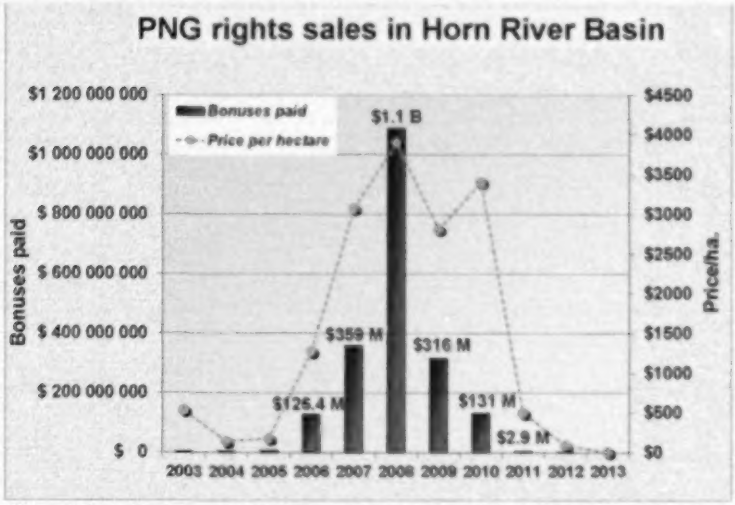


Figure 7. Bonuses from PNG rights sold in the Horn River Basin have leveled off considerably after reaching a record total of $1.1 billion in 2008. Only $23 331 was paid for rights on the southern edge of the basin in 2012. There were no PNG rights sold in 2013.

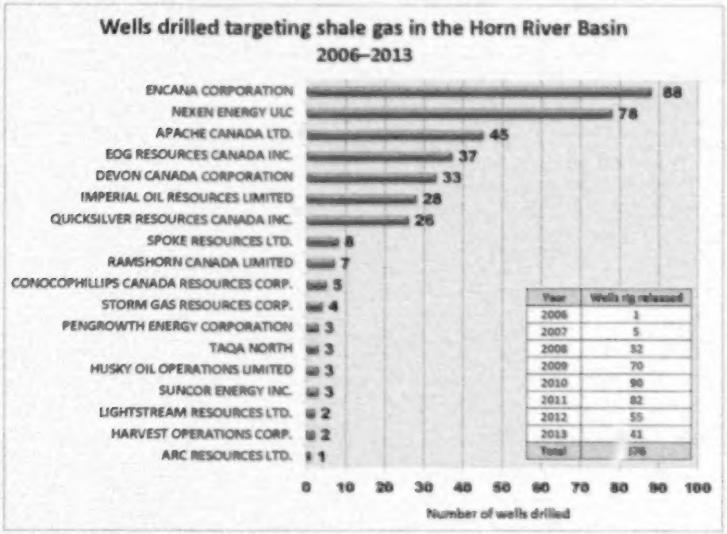

Wells drilled targeting shale gas in the Horn River Basin
2006–2013
ENCANA CORPORATION 88
NEXEN ENERGY ULC 78
APACHE CANADA LTD. 45
EOG RESOURCES CANADA INC. 37
DEVON CANADA CORPORATION 33
IMPERIAL OIL RESOURCES LIMITED 28
QUICKSILVER RESOURCES CANADA INC. 26
SPOKE RESOURCES LTD. 8
RAMSHORN CANADA LIMITED 7
CONOCOPHILLIPS CANADA RESOURCES CORP. 5
STORM GAS RESOURCES CORP. 4
PENGROWTH ENERGY CORPORATION 3
TAQA NORTH 3
HUSKY OIL OPERATIONS LIMITED 3
SUNCOR ENERGY INC. 3
LIGHTSTREAM RESOURCES LTD. 2
HARVEST OPERATIONS CORP. 2
ARC RESOURCES LTD. 1
Year | Wells rig released
2006 | 1
2007 | 5
2008 | 32
2009 | 70
2010 | 90
2011 | 82
2012 | 55
2013 | 41
Total | 376
0 10 20 30 40 50 60 70 80 90 100
Number of wells drilled

Figure 8. Operators in the Horn River Basin have drilled 376 shale gas–directed wells from 2006 to 2013. Drilling peaked in 2010 with 90 wells rig released (British Columbia Oil and Gas Commission, 2014a).

Apache Canada Ltd. has been one of the most active shale gas operators in the Horn River Basin since 2005. The producer's activity has primarily been centered in the areas of **Komie**, **Two Island Lake** and **Ootla** (NTS 094O/7, 8, 9 and 10). Drilling activity during the last two years has been sparse with only one well drilled in early 2013. A **Fortune**–area well listed the Middle Devonian Evie member as its objective and was drilled to a total depth of 2863 m. It is now listed as abandoned. Also during the first quarter of 2013, a 264 km^2

(102 sq. mi.) 3D seismic program was completed (Apache Corporation, 2014a). In 2013, Apache remained focused on advancing its Kitimat LNG project to monetize significant unconventional resources in both the Liard Basin and the Horn River Basin. According to Apache, Kitimat upstream gross production in the Horn River and Liard basins in the fourth quarter of 2013 averaged 158 mmcf/d (63 mmcf/d net to Apache), which is down 9%, mainly due to significant downtime issues with third party processing plants (Apache Corporation, 2014b). Apache recently announced its intention to sell its 50% interest with Chevron Canada Ltd. in the proposed $15 billion Kitimat liquefied natural gas (LNG) export terminal. The upstream partnership had Chevron responsible for marketing the LNG and operating the LNG plant and pipeline assets while Apache would continue to operate upstream development of its 81 000 net hectares (200,000 net acres) in the Horn River Basin.

Storm Resources Ltd. holds 100% working interest on 132 net sections in the Horn River Basin. Its land inventory is primarily along the eastern edge of the basin. Storm's core producing area is in and around the Gote field where the average gross shale thickness for the Middle Devonian Muskwa–Otter Park sequence is approximately 92 m. Since 2009, four wells have been drilled in this 30-section project area. As many as 43 horizontal wells could ultimately be developed, where the best estimate of discovered petroleum initially in place (DPIIP) is 3.1 Tcf gross and 616 Bcf contingent resources (Storm Resources Ltd., 2014a). Storm's first horizontal well in the area (UWI b-19-D/94-P-12) was drilled in 2010 to a lateral depth of 1800 m into the Muskwa–Otter Park. Twelve fracture stimulations were performed with gas production beginning in March 2011. The well is producing at an average rate of 2.4 mmcf/d with cumulative production of 3.5 Bcf as of September 2013 (Storm Resources Ltd., 2014b). Drilling on a second horizontal well in the area was completed in January 2011; the well is awaiting completion with timing dependent on the improvement of natural gas prices.

In August 2012, **Imperial Oil Resources Limited** initiated gas production from an eight-well horizontal pad pilot development project in the **Komie** area (NTS 094O/01). As of September 2013, the pad was producing at an average rate of approximately 40 mmcf/d, helping Imperial evaluate longer-term well productivity and establish full-field development economics in the area (Imperial Oil Limited, 2014). Imperial's first shale gas–directed well (UWI d-47-J/94-O-2) was drilled in the Komie area in early 2009 after receiving experimental scheme approval (now called special innovative technology approval) from the OGC to specifically explore, develop and evaluate the shale gas potential of the Muskwa Formation and the Otter Park and Evie members of the Horn River Formation. Work by Imperial in the Horn River Basin has resulted in multiple productive reservoir intervals with average test rates in the range of 500 thousand cubic feet (mcf) to 1.5 mmcf/d from a single-stage fracture stimulation during a 30 day test period. Recoveries of up to 800 mmcf per fracture stage have also been modelled. Imperial Oil and ExxonMobil Canada Energy are 50-50 partners in the Horn River pilot development project and have more than 130 000 net ha leased in the basin (Adams, 2013).

Production

Since April 2005, more than 600 Bcf has been produced from the Muskwa, Otter Park and Evie members within the Horn River Basin. Daily natural gas production from these formations accounted for approximately 12% of British Columbia's total daily gas production of 4.3 Bcf/d in December 2013 (Fig. 9). Some wells in the Horn River Basin remain on confidential status under the terms of innovative technology approvals, which were previously categorized as special projects and experimental schemes (British Columbia Oil and Gas Commission, 2013).

Liard Basin

Straddling British Columbia's borders with Yukon and the Northwest Territories, the Liard Basin and Liard fold belt region remains a relatively unexplored area situated on the eastern margin of the Cordilleran fold and thrust belt (Adams, 2011). In Northeast British Columbia, the region covers a prospective area of approximately 1 000 000 ha and contains more than 5 km of Cambrian to Upper Cretaceous sedimentary strata. Within the Liard Basin, the Middle Devonian to Middle Mississippian Besa River Formation is an emerging shale gas play that has the potential to contain a resource larger than that found within the Horn River Basin and Cordova Embayment. This formation represents a thick shale sequence resulting from the western shale-out of carbonates spanning the Kakisa to Debolt formations. In addition, this unit contains the western equivalents of shale successions further east, such as the Horn River, Fort Simpson and Exshaw formations (Ferri et al., 2013). In the Horn River Basin, this equivalent stratigraphy is more than 2000 m thick, whereas the outcrop belt of the Besa River Formation is slightly more than 300 m thick.

Land Sale Activity

Producer interest in the Liard Basin has occurred in and around the La Joie and Patry areas, located approximately 110 km northwest of the city of Fort Nelson in the central region of the Liard Basin. To date, the most significant land sales in the Liard Basin occurred at the July 15, 2009 Crown reserve PNG rights disposition, where land brokers purchased seven drilling licences on 46 258 ha for $31.3 million. The purchased parcels were located just north of Patry in NTS 094O/12 and 094O/13. The following year, at the June 23, 2010 PNG rights disposition, 14 licences

totalling $110.4 million on 66 645 ha were purchased to the northwest and southwest of the same area (Fig. 10). Well activity in the area indicates that Apache Canada Ltd. drilled two experimental vertical wells in 2010, one of which was rig released in late December of that year at d-34-K/94-O-5. The d-34-K well lists the Upper Devonian Fort Simpson as the projected formation. There were no PNG rights sales in the Liard Basin in 2011 and 2012.

Two PNG rights parcels were sold in the Liard Basin in 2013, but neither was related to shale gas–directed activity. The sold parcels were located in the Maxhamish area (NTS 094O/11) and were likely purchased by STX Energy Canada Inc. as part of its development of the Cretaceous Chinkeh 'A' pool. Seoul-based STX Energy announced in 2010 that it acquired the Maxhamish gas field from Encana Corporation for $152 million. The gas field is 616 km^2 in size and is estimated to hold 120 Bcf of gas. STX Energy plans to increase the daily production of the gas field from its current 20.5 mmcf/d to 27 mmcf/d (Asia Pacific Foundation of Canada, 2010).

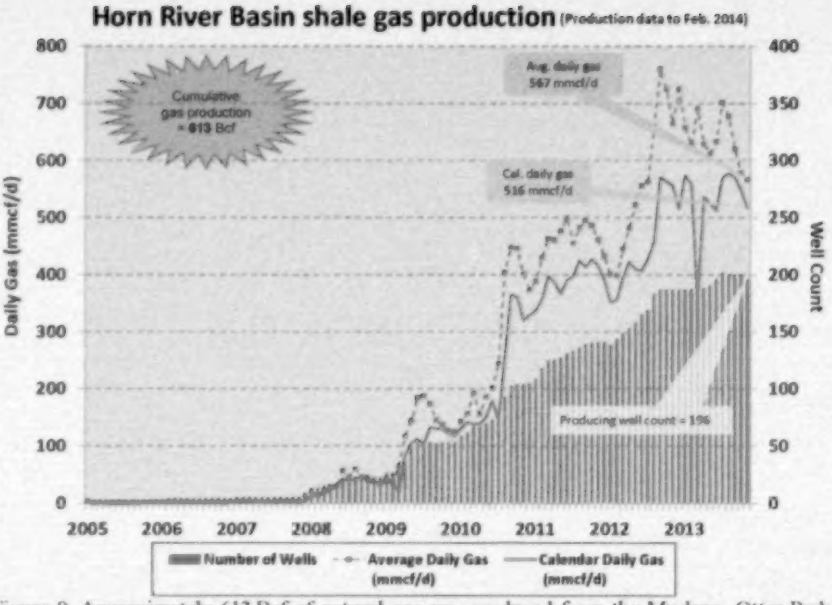

Horn River Basin shale gas production (Production data to Feb. 2014)
Cumulative gas production = 613 Bcf
Avg. daily gas 567 mmcf/d
Cal. daily gas 516 mmcf/d
Producing well count = 196
Daily Gas (mmcf/d)
Well Count
Number of Wells
Average Daily Gas (mmcf/d)
Calendar Daily Gas (mmcf/d)

Figure 9. Approximately 613 Bcf of natural gas was produced from the Muskwa, Otter Park and Evie members within the Horn River Basin from 2005 to February 2014. The average daily calendar rate in February 2014 was 516 mmcf/d from 196 producing wells. Abbreviations: Bcf, billion cubic feet; dly, daily; mmcf, million cubic feet.

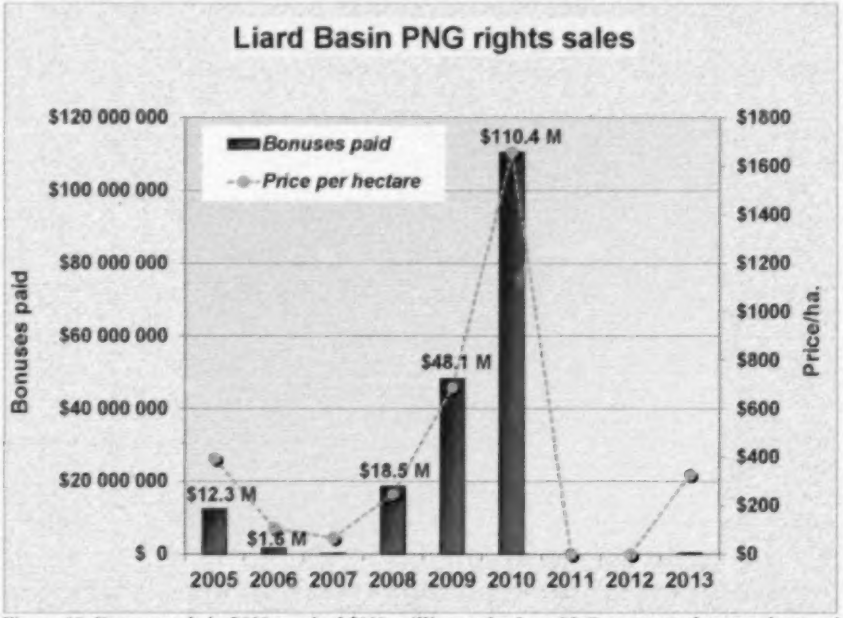


Figure 10. Bonus totals in 2010 reached $110 million at the June 23 Crown petroleum and natural gas rights sale. Fourteen licences covering 66 645 ha were sold in the La Jolie–Beaver River areas (NTS 094N/09 and 094N/16) and to the southwest of the Patry area (NTS 094O/05 and 094N/08). There were no PNG rights sold in the Liard Basin in 2011 and 2012 and only two parcels were sold in 2013 in the eastern section of the Liard Basin (NTS 094O/11).

Industry Activity

Since early 2009, **Apache Canada Ltd.** has been working in the east-central region of the Liard Basin. The producer holds approximately 174 000 ha in the Patry area, with six wells drilled to date targeting Middle Devonian–Early Mississippian shales; three of those are producing into an existing pipeline. In 2012, Apache acknowledged that one of these wells, drilled in the central Liard Basin (Apache HZ Patry d-34-K/94-O-5), recorded a 30 day initial production rate of 21.3 mmcf/d on a six-stage fracturing operation (3.6 mmcf/d per hydraulic fracture). The well was drilled in 2010 to a vertical depth of 3843 m with a horizontal leg of 885 m into the upper Besa River Formation and has an estimated ultimate recovery (EUR) of 17.9 Bcf. It is considered

to be one of the best shale gas resource tests in any of North America's unconventional reservoirs (Apache Canada Ltd., 2012). Apache is targeting the Upper Devonian lower Besa River black shale and estimates that its Liard Basin lands carry a net gas-in-place of 201 Tcf, which could yield net gas sales of 48 Tcf. In 2013, as part of its Kitimat upstream drilling program, Apache successfully drilled two more wells, extending the northern boundary of the play (Apache Corporation, 2014b). The first well was rig released in April 2013 in the Sandy area at b-55-F/94-O-13; the other in July in the Beaver River area at d-87-E/94-O-13 (Fig. 11). Both wells were expected to reach a total depth of greater than 4700 m in the Upper Devonian Besa River. Apache has a superior land position in the Liard Basin and is planning further assessment in the region.

Nexen Energy ULC, a wholly owned subsidiary of **CNOOC Limited**, continues with its commitment to develop shale gas resources in the Liard Basin. Nexen, along with strategic partner **INPEX Gas British Columbia Ltd.**, holds approximately 52 000 net ha of 100% working-interest land in the Liard Basin, which is estimated to contain 5–23 Tcf of prospective resources (National Energy Board, 2013). The first location for appraisal and development in the Liard Basin project area was a single vertical well located in the **La Jolie** area at c-66-I/94-N-9. The high-pressure, high-temperature well took 245 days to drill and reached a bottom-hole depth of 5293 m (rig released on October 8, 2013). The lease-earning well was drilled to evaluate Middle Devonian–Early Mississippian shales.

Paramount Resources Ltd. holds approximately 156 net sections (40 500 net ha) in the Liard Basin that are prospective for shale gas in the Middle Devonian Besa River. In early 2013, the company completed drilling operations on a **Patry**-area horizontal well with a vertical depth of 3400 m and a horizontal leg of 1200 m. The well was brought on production in December 2013 and averaged 3.2 mmcf/d during its first 60 days of production. The well was drilled into a thinner portion of the Besa River shale formation along the eastern portion of the Liard Basin at location b-40-I/94-O-5 (Paramount Resources Ltd., 2014). Operations at Paramount's first Besa River shale gas evaluation well at d-57-D/94-O-12 in the **Dunedin** area were suspended in the spring of 2012 because of warm weather. That well resumed operation in September 2013 and was drilled to a total measured depth of 6000 m, including a 1600 m horizontal leg. According to Paramount, significant pressures were noted during the drilling operations of this well. The producer has stated that the Besa River shale in the Dunedin area (central portion of the Liard Basin) is approximately four times thicker than in the Patry area located further east. Paramount plans to complete this well in late 2014, and pending test results, will complete tie-in operations in 2015. Another well in the Dunedin area began drilling operations in late February 2014. The vertical shale gas exploration well is located at d-71-G/94-N-8 and is being drilled to preserve lands in the area. Paramount has indicated that the Liard Basin holds an original gas-in-place (OGIP) of 170–500 Bcf per section with an expected recovery of 20% (Paramount Resources Ltd., 2013).

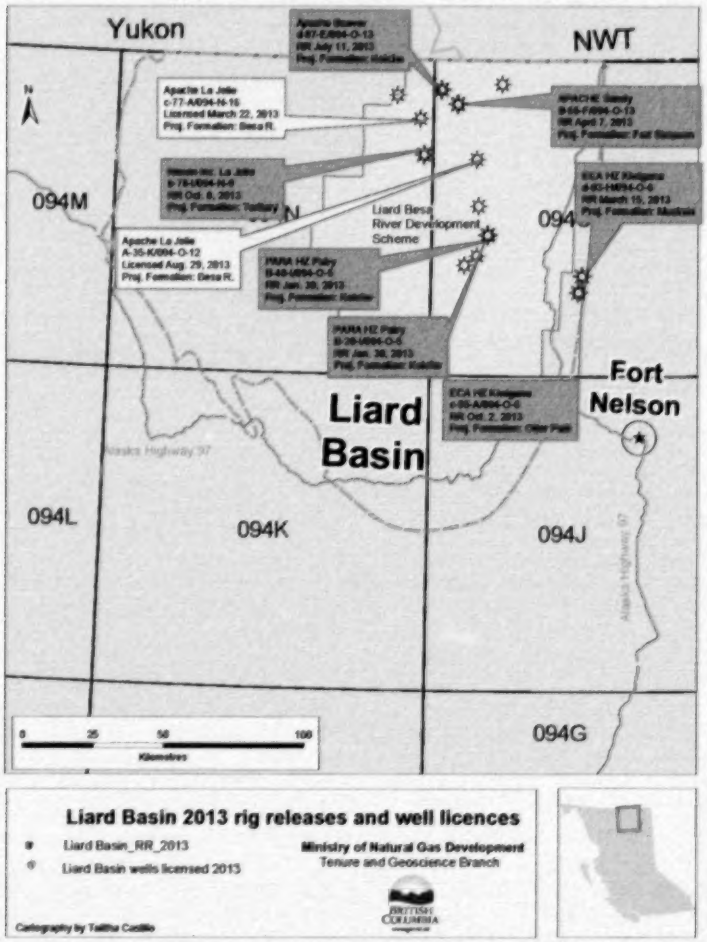


Figure 11. Recent rig releases and well licensing activity in the Liard Basin. Abbreviations: Proj., projected; R, river; RR, rig released.

The **Beaver River** area lies within the Liard Basin and is located west of the Kledo–Bovie Lake fault near the British Columbia–Yukon border. It is a relatively unexplored area and is of interest to producers looking to evaluate shale gas prospects in the Upper Mississippian Mattson–Golata intervals and the extensive Devonian–Mississippian Besa River. **Transeuro Energy Corp.** has been conducting operations in the Beaver

River field to evaluate these shales as a potential resource play and has had some encouraging results from testing completed to date. In 2013, gas production was from three wells with an average combined rate of 1.4 mmcf/d recorded in May 2013. Transeuro has been in discussions with a third party concerning the purchase of interest holdings in the Beaver River field. With the absence of working capital in the area, production from the three producing wells has been shut in since May 2013 and will resume once Transeuro has secured a merger or acquisition (Transeuro Energy Corp., 2014). The next phase for shale appraisal in the Beaver River area would have been a program that focused on Nahanni exploration targets and the potential for initial flow rates of 15 mmcf/d per well. The program would involve multiple wellbore re-entry, hydraulic fracturing and acid stimulation. Further appraisal was to target up to 14 horizons in six wells across the field to assess the commercial potential of all three horizons (Mattson, Besa River and Muskwa).

Cordova Embayment

The Cordova Embayment covers an area of 270 000 ha and sits approximately 130 km northeast of Fort Nelson in the far northeastern corner of the province. The area lies to the east of the well-established Devonian Jean Marie gas production and deeper exploration targets such as the Slave Point and Pine Point (Keg River) carbonates. More than 340 wells have been drilled in the basin since the early 1960s; most of those are in the Helmet, Helmet North and Midwinter West areas. Since 2008, approximately 40 of those wells have targeted shale gas.

Land Sale Activity

The Cordova Embayment has not seen land sale activity since 2010 when bonuses reached $261 million for the year (Fig. 12). Producing companies in the Cordova Embayment have attained their competitive land positions and continue to focus on drilling and resource appraisal.

Industry Activity

Because of its geological similarity with the Horn River Basin, the Cordova Embayment is a logical place to conduct exploration for shale gas plays. The presence of free gas in natural fractures was evident in a well drilled by Chevron Standard Ltd. in the North Helmet area in 1976. A core description from a Devonian shale section noted that the entire core had "bleeding gas from hairline fracture planes" (Dobek, 1976). With increasing depth of coverage in the Cordova Embayment, appropriate testing and completion strategies can be determined and the relative success of recompletion versus new drills can be evaluated.

Penn West Exploration Ltd. has been evaluating the Devonian shale sequence in the **Helmet North** area within the Cordova Embayment since 2008. The producer has acquired more than 95 000 ha in the region and, until late 2013, continued to direct capital towards its Cordova Gas project. In 2013, Penn West continued with assessment and appraisal work on its Cordova joint venture (Mitsubishi Corporation has been a joint venture partner with Penn West to develop shale gas in the Cordova Embayment since 2010) with the drilling of seven horizontal wells on several multiwell pads (Fig. 13). Completion operations are expected to be conducted on these wells in 2014 (Nickle's Daily Oil Bulletin, 2013b). In late 2013, Penn West announced plans to sell its shale gas assets in the Cordova Embayment as part of the second phase of a massive divestiture program (Penn West Exploration Ltd., 2013).

Nexen Energy ULC and **INPEX Gas British Columbia Limited** remain in the early stages of development in the Cordova Embayment. The joint interest partners will continue with a series of drilling, well completion and production testing programs in the **Helmet** area. Nexen has acquired more than 3300 ha in the region and now holds a 60% operated interest in its joint venture lands with INPEX, which holds the remaining 40%. Nexen did not drill any wells in the Cordova Embayment in 2013. The previous year,

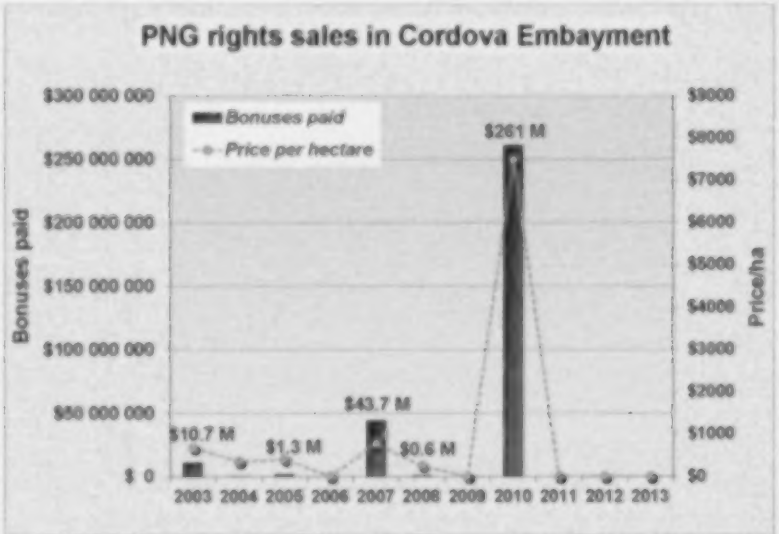


Figure 12. The Cordova Embayment saw a sizable increase in the level of land sale activity in 2010, with bonuses reaching a high of $261 million, achieved at the June 23 Crown PNG rights sale, where 18 licences and 4 leases covering 34 877 ha were sold in NTS 094P/10 and 094P/15. No PNG rights have been sold in the Cordova Embayment since 2011, but drilling continued with 40 wells rig released during the last three years.

Nexen drilled two horizontal wells; one targeted the Upper Devonian Muskwa and the other targeted a 14 m window within the Evie member (Middle Devonian). Both wells have been listed as cased since the spring of 2012.

Production

As of December 2013, 18 wells in the Cordova Embayment were producing gas from Devonian shale sequences in the Muskwa, Otter Park and Evie (Fig. 14). Cumulative production from January 2008 to December 2013 reached 22.3 Bcf from 21 wells drilled mostly by Penn West Exploration Ltd., with one by Canadian Natural Resources Limited. Prior to shale gas exploration, the Cordova Embayment saw gas production primarily from the Upper Devonian Jean Marie and the Middle Devonian Slave Point and Keg River in the Helmet North and Midwinter areas.

Bivouac-Muskwa

The Devonian Muskwa Formation is being extensively developed for its shale gas potential in the Horn River Basin and Cordova Embayment, where gas production is predominantly dry. Further to the southeast, on the northern edge of the Peace River Arch (PRA), there has been some industry activity focusing on the Muskwa shales, specifically in the Bivouac area (NTS 094I/08 block). In this area of Northeast British Columbia the Devonian Muskwa Formation sits on the Beaverhill Lake Formation and is thought to have localized faulting that has trapped the Muskwa shales and allowed condensate to migrate through the thick Fort Simpson shales (Ferri and Griffiths, 2014). The Bivouac field covers an area of more than 30 000 ha and sits approximately 130 km southeast of Fort Nelson along the British Columbia–Alberta border. It has well-established gas production from the Mississippian Debolt and from deeper targets in the Upper Devonian Jean Marie carbonates.

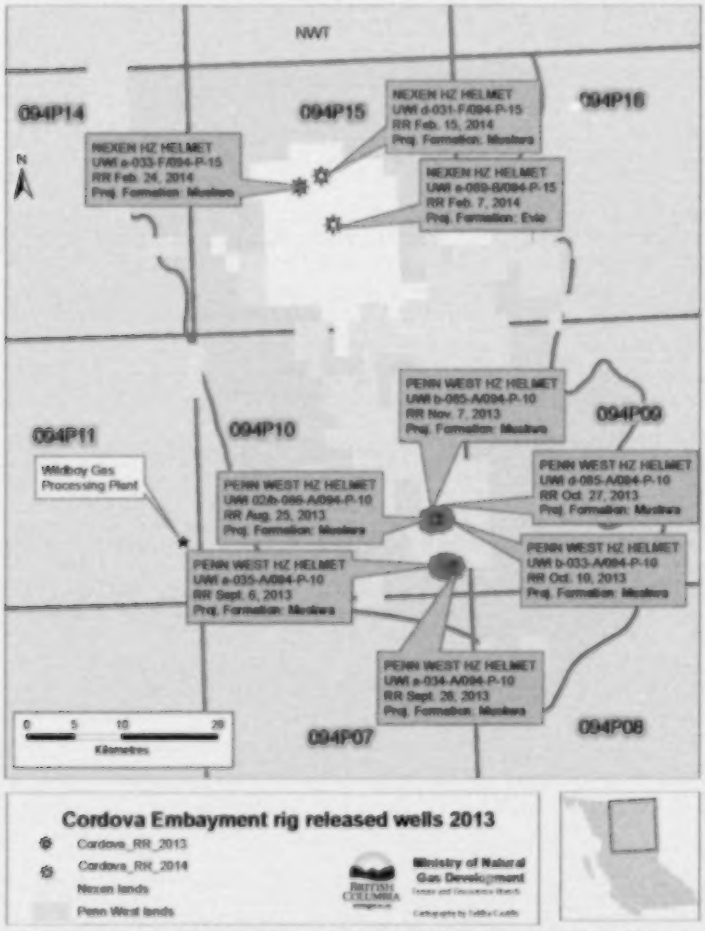


Figure 13. From 2010 to 2013, virtually all well activity in the Cordova Embayment was directed towards shale gas targets. Penn West Exploration Ltd. was again the most active operator in the region in 2013 with seven horizontal wells recorded as rig released. Nexen Energy ULC did not rig release any wells in 2013, but in early 2014, it completed drilling operations on three wells. These wells will remain on confidential status until August 2014. Abbreviations: Proj., projected; RR, rig released.

Land Sale Activity

So far, only two of British Columbia's PNG rights sales have resulted in parcels being purchased in the Muskwa play area at Bivouac. At the December 2013 PNG rights disposition, land broker Standard Land Company Inc. paid a bonus of $64 319 for a 1085 ha lease (an average of $59/ha). A month later, at the January 2014 land sale, Basm Land & Resources Ltd. paid $89 845 for a 2716 ha licence at an average of $33/ha. Although the parcels sold are not indicative of a robust regional resource play, it could designate a narrow zone of condensate potential in this district of Northeast British Columbia.

Industry Activity

Husky Energy Inc. is pursuing a number of initiatives to advance its oil and liquids-rich gas resource plays in Western Canada. In 2013 and early 2014, Husky drilled five wells in the Bivouac area targeting the Muskwa shales (Fig. 15). The first horizontal well (Husky HZ Bivouac a-55-B/094-I-08) was drilled in the area in January 2013 to a true vertical depth of 1827.8 m and a measured depth of 3620 m. At this well the Muskwa Formation is approximately 27 m thick and occurs at a depth of 1819 m. An 18-stage nitrified slick water fracture treatment using plug and perf technology was performed along a 1600 m horizontal leg.

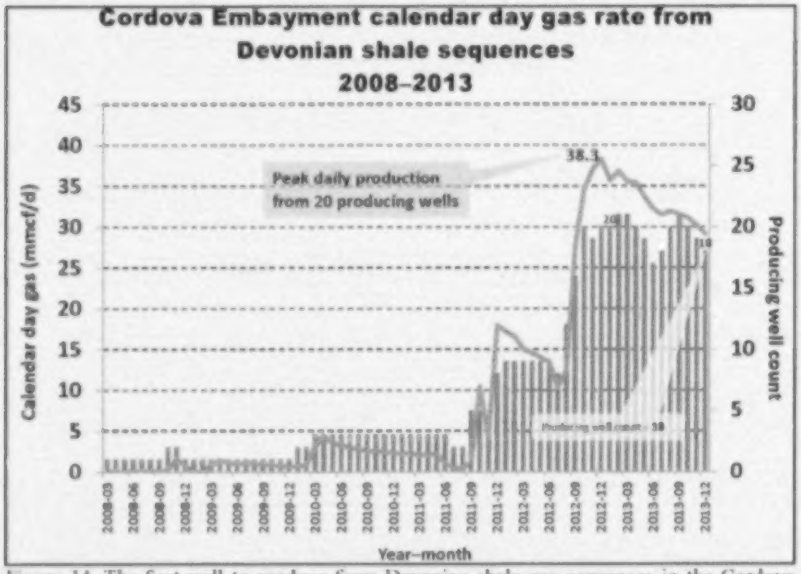


Figure 14. The first well to produce from Devonian shale gas sequences in the Cordova Embayment was by Canadian Natural Resources Limited in March 2008. Between that date and December 2013, another 20 shale gas–directed wells began production. Peak production volumes occurred in December 2012 when 20 wells were producing at a combined calendar day rate of 38.3 mmcf/d. At year-end 2013, 18 wells were producing at a calendar day rate of 29.2 mmcf/d. Cumulative production to the end of 2013 was more than 22.0 Bcf with 88% of that production occurring between January 2012 and December 2013.

Figure 15. The Muskwa Formation represents a widespread, organic-rich unit in the Western Canada Sedimentary Basin and is identified as one of the main source-bed horizons (Ferri and Griffiths, 2014). Husky Energy Inc. is pursuing a number of initiatives to advance its oil and liquids-rich gas resource plays in Western Canada, including the exploration of Muskwa shales in the Bivouac area. Abbreviations: Proj., projected; RR, rig released.

Production

As of April 2014, one well in the Bivouac area (UWI b-33-B/094-I-08, Surface a-55-B/094-I-08) was producing gas from the Devonian Muskwa Formation. During the first four-month production period (September to December 2013) the daily average gas rate was 1.2 mmcf/d and 21.5 barrels/d of condensate. Cumulative gas production from September 2013 to April 2014 was almost 140 mmcf.

Montney Play Trend

Since 2007, the development of gas from the sandstone, siltstone and shale sequences has surpassed the expectations of many producers working along the Montney play trend. At year-end 2012, the play trend accounted for 33% of British Columbia's remaining raw gas reserves of 40.2 Tcf and is now one of the most active natural gas plays in North America (British Columbia Oil and Gas Commission, 2013). Before that period, development of gas in the Montney unconventional play trend area was restricted to vertical drilling for poor-quality, conventional fine-grained sandstone reservoirs (British Columbia Oil and Gas Commission, 2012). The Triassic Montney Formation is a thick, regionally charged formation of unconventional tight gas and shale gas distributed over an area extending from north-central Alberta to northwest of Fort St. John in Northeast British Columbia (Fig. 16). The fairway covers approximately 2.9 million ha in the South Peace region and includes major facies of fine-grained shoreface, shelf siltstone to shale, fine-grained sandstone turbidites and an organic-rich phosphatic shale. In recent years, producers have pushed land sale and drilling activity northward in the fairway, which offers the advantage of producing natural gas liquids and condensate, as opposed to the drier shale gas areas in the extreme northern regions of the province.

Land Sale Activity

Annual bonuses garnered from PNG rights sold within the greater Montney exploration and development fairway reached a peak of $1.32 billion in 2008 (Fig. 17). The record land sale bonuses collected that year can be directly correlated with an industry shift to incorporate unconventional gas reservoirs, which include Triassic targets such as the Upper, Middle and Lower Montney, as well as the Doig and Doig Phosphate. Land sale bonuses have

dropped steadily since that period with 2012 bringing in total bonuses of $121 million. In 2013, bonuses collected from land sales within the Montney play trend jumped by 81% from the previous year, reaching a total of $219 million or 98% of total bonuses collected in the province. The highest monthly bonus total was collected at the November 2013 PNG rights disposition. Four drilling licenses and three leases, totalling 11 484 ha (all for Montney rights), accounted for almost the entire $54.5 million in bonuses collected at the November disposition. The most expensive parcel was purchased in the Laprise Creek area where operators are pushing the boundary of the Montney fairway to the northeast. Charter Land Services Inc. (land broker) tendered the highest bonus bid at the auction with $42.41 million for a 6148 ha drilling licence on the northeastern edge of the British Columbia Oil and Gas Commission's defined regional Northern Montney Field. The broker paid an average of $6897/ha for PNG rights to several block units in NTS 094H/05 and 094G/08. Operators such as Progress Energy Canada Ltd., UGR Blair Creek Ltd. and Black Swan Energy Ltd. have conducted horizontal drilling along a northwest–southeast trend to the southwest of this expensive licence in the Bubbles, Jedney and Beg areas.

Figure 16. Petroleum and natural gas rights sold and wells drilled within Montney play region from 2012 to April 2014. The main play area of the Montney trend covers approximately 2.9 million ha (7.2 million acres) in the Fort St. John–Dawson Creek region of Northeast British Columbia and extends geographically up to the Trutch area.

Industry Activity

The Triassic Upper Montney zone continues to offer exceptional growth in production, particularly from such fields as **Monias**, **Dawson Creek**, **Swan Lake** and **Tupper Creek**. The Upper Montney is limited by depth within the Montney play region; it is shallow in the northeast and deepens to the southwest. Technological advances and the application of new horizontal well techniques are a major component to unlocking the potential of the Montney resource. These techniques are giving producers such as Progress Energy Canada Ltd. and Talisman Energy Inc. the opportunity to target the Upper, Middle and Lower Montney, and Doig in areas of the northern Montney play region, which is bounded by the **Caribou**, **Lily Lake**, **Altares**, **Town** and **Gundy Creek** fields. This widespread expansion of the productive north Montney fairway is located in a relatively

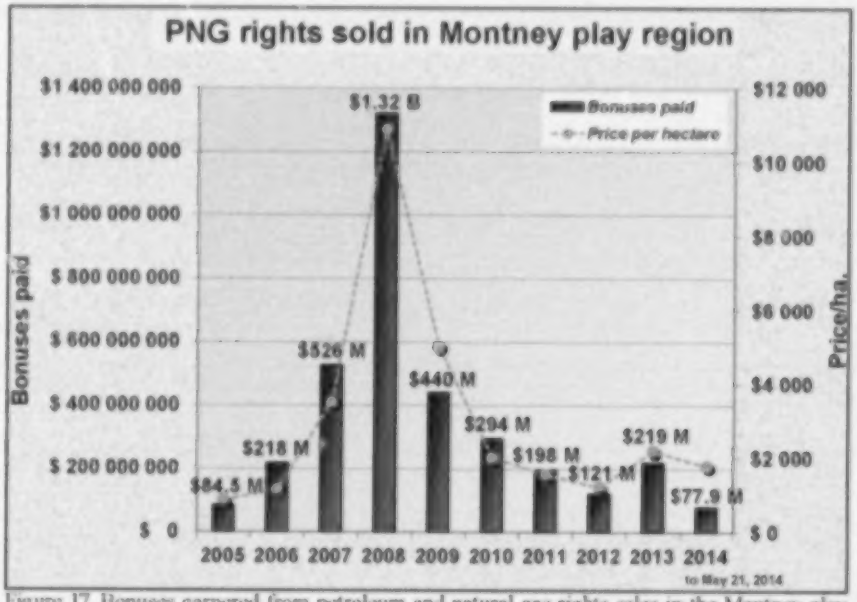


Figure 17. Bonuses garnered from petroleum and natural gas rights sales in the Montney play trend since 2005.

undrilled region of Northeast British Columbia and has been experiencing a surge of interest during the last two years. In addition to unconventional Montney gas, conventional Debolt gas thrust traps are targeted in this region. A total of 465 wells were rig released within the Montney play region in 2013 (Fig. 18). More than 93% listed the Triassic Doig and Montney formations as the projected target.

Progress Energy Canada Ltd., a subsidiary of global LNG player **Petroliam Nasional Berhad (PETRONAS** of Malaysia), plans capital spending of $2 billion in 2014, most of it weighted towards the northern Montney fairway in the Northeast British Columbia's Foothills region (Nickle's Daily Oil Bulletin, 2014b). Its North Montney joint venture, which contains a combination of liquids-rich and dry gas assets, continues to expand the areal extent of productive Montney fairway with full-scale commercial developments and a goal of delivering 2.0 Bcf/d to **Pacific NorthWest LNG** by 2019. Progress Energy, one of the busiest drillers in Canada and certainly the most active in British Columbia, drilled a total of 143 wells in the north Montney region in 2013. In 2014, the producer plans to operate an average of 25 rigs and estimates drilling 170 wells (Progress Energy Canada Ltd., 2014a). Progress is drilling to establish 15 Tcf of proved plus probable reserves by year-end 2014 when PETRONAS will decide whether to proceed with its Pacific NorthWest LNG export facility on Lelu Island in the District of Port Edward (near Prince Rupert). In 2013, Progress tripled its proved plus probable reserves at its North Montney joint venture to more than 8 Tcf. It continues to build its position on its north Montney lands with recent acquisitions of assets from Talisman Energy Inc. Progress recently acquired land interest from Talisman in the **Kobes** area and a 50% interest in the **Cypress** and **Farrell Creek** areas. It also closed an acquisition in the **Julienne Creek** area, which included four Montney wells awaiting completion and approximately 13 600 ha of undeveloped Montney lands (Progress Energy Canada Ltd., 2014b). The producer was one of the first movers in the north Montney region and has now identified a potential drilling inventory of 2500–7500 locations, encompassing both the Upper and Lower Montney targets of the Lower Triassic. The producer uses development pods in its drilling process; each pod lays out 80 drilling locations in a concentrated area with a centralized facility capable of processing 50 mmcf/d. Progress Energy Canada Ltd. has selected **TransCanada Corporation** to design, build, own and operate its proposed $5 billion **Prince Rupert Gas Transmission** project, which will transport natural gas primarily from the north Montney gas-producing region to the Pacific Northwest LNG export facility on Lelu Island. The large diameter pipeline would have an initial capacity of 2 Bcf/d and an estimated in-service date of 2018 or early 2019 (Progress Energy Canada Ltd., 2013).

Shell Canada Limited continues to redefine and restructure its growth on a global perspective; this includes a major review of its resource portfolio in the Upstream Americas Onshore business. Shell is selling its Eagle Ford, Mississippi Lime and US

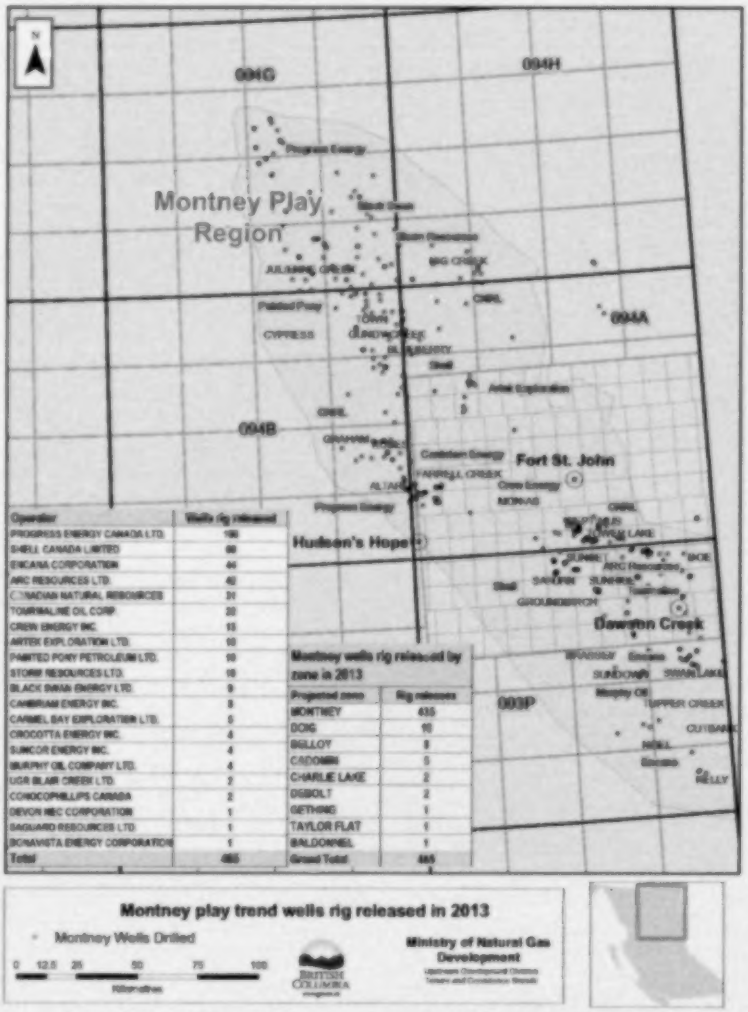


Figure 18. The key active producers operating in the Montney play trend in 2013. The Montney region accounted for 82% of the 568 wells drilled in British Columbia in 2013. The Triassic Doig and Montney formations encompassed most of the projected zones targeted by producers.

Rockies liquids-rich shale gas assets because of mixed drilling results, but plans to grow activity in the **Sunset Prairie-Groundbirch** complex within Northeast British Columbia's Montney play region. Shell holds PNG rights totalling more than 300 sections (80 000 ha) in the complex, which now include several natural gas processing plants and more than 900 km of pipeline. The latest production figures from Shell show that 330 mmcf/d is being produced from more than 300 wells (Shell Canada Limited, 2014a). Wells at Groundbirch are drilled with a mix of single and multiwell pads at moderate target depths of 2200–3000 m. The Triassic Montney target lies in a sequence of siltstone, sandstones and shales more than 150 m thick. Shell drilled 53 of its 60 Montney trend wells in the Sunset Prairie–Groundbirch complex in 2013. The remaining wells were drilled in the **Gundy Creek** and **Town** areas where Shell is focusing on the potential for future development. In the spring of 2013, Shell completed drilling on its longest monobore lateral section in the history of its Upstream Americas Onshore business. The total measured depth of the well was 6250 m, which included a lateral leg of 3897 m. The well, located in the **Sunset** area (UWI 102/12-18-79-18W6), was drilled in only 25 days with the lateral portion drilled using only one drill bit (Shell Canada Limited, 2014b). It was one of five long lateral wells drilled on a pad. The well became an active gas producer in mid-January 2014 at a rate of 11.2 mmcf/d over four days. Horizontal wells with long reach laterals such as this one could set a new standard for field development in the Groundbirch complex and could ultimately reduce the number of wells needed to successfully produce from Montney targets. Shell Canada is one of four companies that have formalized a joint venture partnership with LNG Canada to develop a proposed LNG export project in Kitimat, British Columbia. The other joint venture partners are **PetroChina Corporation**, **Korea Gas Corporation** (KOGAS) and **Mitsubishi Corporation**. Shell's Groundbirch area assets are a good supply link to an LNG liquefaction plant off the coast of British Columbia.

Natural gas production from the sandstone, siltstone and shale sequences of the Triassic Montney continues to exceed **Encana Corporations's** expectations. The Montney resource region is a good fit with Encana's objective to accelerate liquids growth and optimize base gas production. Encana's net land position in the Montney region, which encompasses areas of Northwest Alberta and Northeast British Columbia, is approaching 234 000 ha. In 2013, the company rig released 45 wells within the British Columbia portion of the resource play. Listed as one of its six key growth assets, Encana plans to accelerate the development of oil and liquids-rich areas of the Montney play and estimates drilling 80–85 net wells in the region in 2014. The producer is also forecasting net capital spending of $800–900 million in 2014 with net production rates of 7200–7500 barrels/d of oil/field condensate, 12 000–12 500 barrels/d of NGLs and 510–530 mmcf/d of natural gas. Encana's assets in the **Cutbank Ridge** resource play, which basically covers five development areas within the southern portion of the Montney play trend in British Columbia, consist of gas production from the Montney, Cadomin and Doig formations. Most of the 45 wells drilled in Encana's Cutbank Ridge play area in 2013 were directed towards Montney development with some targeting the Doig and Cadomin formations. The five development areas in the Cutbank Ridge play in Northeast British Columbia are **Montney** (**Tower**, **Dawson North**, **Dawson South** and **Tumbler Ridge**), **Cadomin** and **Steeprock Doig** (Fig. 19). In early 2012, Encana entered into a partnership agreement with **Mitsubishi Corporation** to jointly develop natural gas resources in certain Cutbank Ridge lands. Mitsubishi agreed to invest approximately $2.9 billion for a 40% interest in the partnership with Encana's operatorship of the assets being maintained. Natural gas production volumes from Encana's entire Montney play region in 2014 are expected to reach 500–530 mmcf/d (Encana Corporation, 2014).

Using its significant operational expertise in developing tight, low-permeability formations, **ARC Re-**

Figure 19. Encana's Montney resource is well positioned within its Cutbank Ridge play development area. The producer's natural gas-in-place per section is one of the highest in the region with estimates of 130 Tcf and 1–2 billion barrels of petroleum initially in place (Encana Corporation, 2013). Encana's Cutbank region has a 150 km wide and 600 km long aerial extent within the southern portion of the Montney fairway. Abbreviation: Tcf, trillion cubic feet.

sources Ltd. (ARC) continues to be a leading operator and producer in the Montney play trend. The company was one of the first operators to establish successful horizontal completion methods along the trend with its early work in developing Upper Montney shale gas in Northeast British Columbia's **Dawson** area (Fig. 20). It has now expanded its land holdings in the Montney fairway to 500 net sections (130 000 ha), which include its West Montney lands at **Sundown**, **Sunrise**, **Sunset Prairie**, **Septimus**, **Tower Lake** and further north in the **Attachie** and **Blueberry** areas. During the first three months of 2014, daily production from these Northeast British Columbia assets was 253 mmcf/d of natural gas, 2496 barrels/d of oil and 1555 barrels/d of natural gas liquids (ARC Resources Ltd., 2014a). According to an independent resource evaluation conducted by **GLJ Petroleum Consultants Ltd.** in 2013, the discovered resource potential of ARC's Northeast British Columbia Montney areas is significant at 30.4 Tcf of DGIIP, up from 27.5 Tcf in 2012 (ARC Resources Ltd., 2014b). ARC's most productive area is the Dawson field, where volume rates reached 158 mmcf/d of natural gas and 970 barrels/d of liquids at the end of 2013. Nine natural gas wells were drilled in the area in 2013; ARC plans spending of $54 million on drilling and development activities in 2014. The 2014 drilling program at Dawson entails maintaining production levels to keep facilities full through 2014 and into 2015. In the Parkland–Tower Lake areas, ARC produces a combined total of approximately 59 mmcf/d of gas and 2570 barrels/d of liquids. The economically favourable areas produce predominantly light oil and free condensate with additional liquids in the gas stream (ARC Resources Ltd., 2014c). In 2013, 15 liquids-rich natural gas wells completed drilling in the Parkland area and 13 oil wells were drilled at Tower. In 2014, $191 million in capital spending will be executed in the Parkland and Tower Lake areas. ARC is planning to drill 13 natural gas wells in the Parkland area and 17 oil wells at Tower to partially fill a recently completed 60 mmcf/d gas processing and liquids handling facility. In the Sunrise area, natural gas production reached 21 mmcf/d in the fourth quarter of 2013 with production coming from three layers of the Montney Formation. ARC drilled two horizontal wells in late 2013 as a forerunner to full-scale development drilling and an infrastructure program planned for 2014 and 2015. Capital spending of $120 million along with the drilling of 14 natural gas wells is planned for 2014; production in the area is expected to grow to 60 mmcf/d. Further north in the Attachie area, ARC completed drilling on one well in 2013 and also initiated pilot production from two wells on its interest lands in the western portion of the area. ARC will continue to assess options for commercial development and infrastructure requirements on its properties at Attachie.

During the last five years, **Talisman Energy Inc.** had attained large, contiguous land holdings in the Montney play trend. It held approximately 74 000 net ha along the fairway with a contingent resource of 29 trillion cubic feet equivalent (Tcfe; Talisman Energy Inc., 2013). Talisman's major focus was in the greater **Cypress**, **Farrell Creek** and **Groundbirch** areas where average net production from wells was 71 million cubic feet equivalent per day (mmcfe/d) in the second quarter of 2013 (Talisman Energy Inc., 2014a). In the first quarter of 2014, Talisman completed the sale of 75% of its assets in the Montney play trend to Progress Energy Canada Ltd. The transaction represents the sale of its Montney play position in the Greater Cypress and Farrell Creek areas (51 400 ha) where production as of October 1, 2013 was 65 mmcfe/d. Talisman will retain its Groundbirch and Saturn area assets in Northeast British Columbia, which includes approximately 19 425 net ha (48 000 net acres) of prospective land in the Montney play (Talisman Energy Inc., 2014b). The bulk of Talisman's well activity in 2013 was within its

ARC Resources Ltd. growth engine in the BC and Alberta Montney

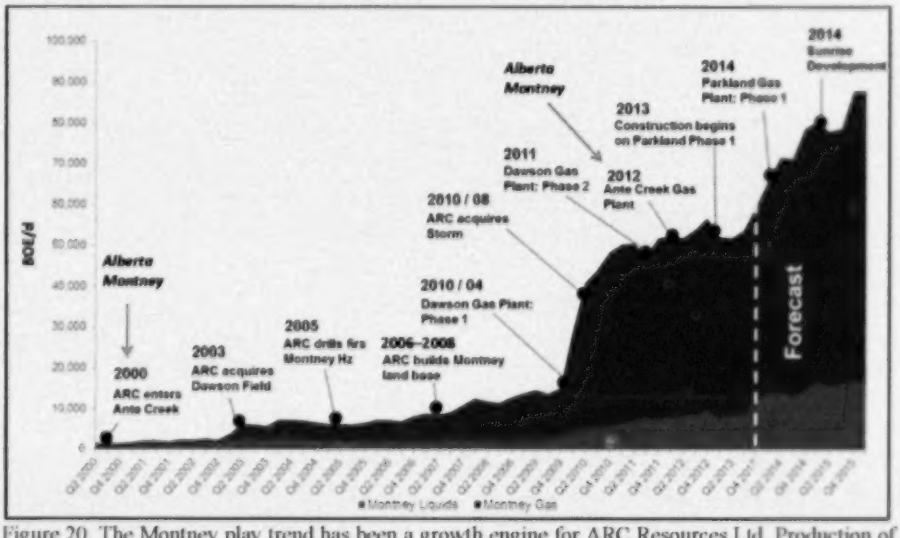


Figure 20. The Montney play trend has been a growth engine for ARC Resources Ltd. Production of natural gas and liquids from its Montney operations in Northeast British Columbia and Alberta have increased substantially, particularly since 2003 when ARC acquired the interest in the Dawson area (Northeast British Columbia). Early pilot data from ARC indicate decreasing costs and increasing estimated ultimate recoveries. ARC achieved record fourth quarter production of 59 560 barrels of oil equivalent (BOE) from its Montney activities in 2013 (modified from ARC Resources Ltd., 2014b).

Farrell Creek asset region, specifically in the **Altares** and **Graham** areas (NTS 094B/01 and 094B/08) where Talisman targets the Upper and Lower Montney and Doig. Thirty-four wells were rig released during the year with a reduction in gas-directed activity and the allocation of more capital towards liquids-rich opportunities. In early 2011, Talisman sold a 50% net working interest in its Cypress 'A' Montney assets to South Africa's **Sasol Limited**. The $1.05 billion deal encompassed a plan to develop stranded gas in Northeast British Columbia by converting Talisman's significant Montney gas resource into liquids using Sasol's expertise in gas-to-liquids conversion. A similar deal with Sasol was closed in late 2010 with Talisman's Farrell Creek assets.

Canadian Natural Resources Ltd. (CNRL) holds a significant unconventional land asset base of approximately 422 000 net ha (more than 1 000 000 net acres) along the Montney fairway. One of CNRL's main project areas is the Septimus field, where it continues with its concentrated liquids-rich drilling program. An increase in CNRL's natural gas volumes to 1.18 Bcf/d was realized in the first quarter of 2014 as a result of the drilling program and the expansion of a Septimus-area plant in late 2013 (Nickle's Daily Oil Bulletin, 2014c). The increase in gas volumes improved sales capacity in the area to 125 mmcf/d and 12 000 barrels/d of liquids (Canadian Natural Resources Ltd., 2014). CNRL drilled 26 wells at Septimus in 2013 and another 13 during the first four months of 2014.

In the second quarter of 2014, **Tourmaline Oil Corporation** became the fifth largest Montney producer in Western Canada, with production reaching 33 000–35 000 BOE per day. The producer has been a significant participant in recent British Columbia Crown land auctions and, as a result, has built a drilling inventory of more than 800 future development locations. Its Northeast British Columbia activities are focused in the **Sunrise-Dawson** play area where it believes the Triassic Montney is the thickest, most overpressured and liquids rich. Tourmaline's Sunrise-Dawson play has three distinct overpressured Montney horizons to exploit. These vertically stacked turbidite lobes all exhibit high deliverability from horizontal drilling (average rates from 3.8 to 4.9 mmcf/d) with a reasonably strong liquids content of 35–50 barrels/mmcf. In April 2014, production from the area was 175–180 mmcf/d of natural gas and 3500–4000 mmcf/d of condensate and NGLs (Tourmaline Oil Corporation, 2014). Tourmaline has drilled a total of 99 Montney wells in the Sunrise-Dawson play and tested 97 of those. During the last two and a half years of drilling, the average initial production test rate was 11.4 mmcf/d with an average liquids rate of 315 barrels/d. Tourmaline drilled 22 horizontal gas wells in the Dawson-Sunrise complex in 2013; another 11 have been drilled in 2014 (to May 2014). The company has not only seen improved capital performance and lower well costs in the complex, but has also taken its successful completion technology used in the area and employed it in the deeper, tighter and higher pressure areas of the Montney—specifically in the Sundown area, where initial production rates have increased threefold compared to historic levels.

Crew Energy Inc. has increased its land interests in the Montney region to 452 sections, further enhancing its competitive land position in the overpressured regional Montney complex. Crew purchased approximately 75 sections of highly prospective Montney rights in the **Septimus** and **Groundbirch** areas in the first quarter of 2014. The Septimus area experienced 74% growth in production in 2013 with wells testing at initial rates as high as 15 mmcf/d. Total activity at Septimus in 2013 resulted in 14 wells being drilled; all were targeting liquids-rich gas. Crew also continued to evaluate Montney potential at its **Attachie**, Groundbirch and **Tower** area properties. Investment in Montney production infrastructure is estimated at $35 million for the remainder of 2014. Eighteen wells are planned in 2014 to initially fill a new 60 mmcf/d raw gas facility at Septimus. Crew anticipates this facility to be on-stream in mid-2015. In the first quarter of 2014, Crew drilled one well at Attachie, three wells at Septimus and is currently drilling its first horizontal well at Groundbirch. It has also begun operations on the first well of a six-well pad at Septimus. Crew's Montney resource has significant upside with TPIIP (total petroleum initially in place) of 109 Tcfe (Crew Energy Inc., 2014).

Artek Exploration Ltd. has planned a 2014 capital investment program that strikes a balance between production growth and pool extension in the Triassic Doig high-yield, condensate-rich areas of **Inga** and **Fireweed**, located in the north-central region of Montney play trend (Artek Exploration Ltd., 2014a). The 2014 program includes seven horizontal wells targeting the condensate-rich Doig play and another three wells targeting the Montney. The program will represent approximately 70% of Artek's 2014 capital expenditures budget of $61–66 million. Artek has increased its landholdings in the Inga area to almost 21 000 net ha with multiple transportation and processing options, allowing it to pursue greater liquids extraction alternatives. Artek drilled 10 wells in the Inga area in 2013, which included a successful Doig horizontal well and Montney horizontal well drilled from the same surface pad at 10-17-87-23W6. The Doig well was drilled into a significant pool extension of Artek's new Inga South Doig discovery/extension area, which previously encountered particularly thick Doig sands and high natural gas liquids rates (Artek Exploration Ltd., 2014b). First month gross production rates from Artek's first 15 horizontal wells drilled at Inga (to the second quarter of 2013) have averaged 1100–1200 BOE/d with 50% natural gas liquids (Artek Exploration Ltd., 2014c).

Storm Resources Ltd. has acquired approximately 39 700 net ha (98 000 net acres) of undeveloped

land in the **Umbach** area in the northwest region of the Montney play trend (NTS 094H/03). The area is prospective for liquids-rich natural gas with Storm reporting first-quarter 2014 average production of 3559 BOE/d, representing 535% growth from the first quarter of 2013. Natural gas liquids recovery was 38 barrels/mmcf of natural gas sales, which included 60% higher-priced condensate plus pentanes (Storm Resources Ltd., 2014c). Storm's activity at Umbach entails three project areas: Umbach North with 33 net sections and 60% interest on most lands; Umbach South with 87 net sections and 100% working interest; and Nig Creek with 20 net sections and 100% working interest. Storm acquired its land interest in the **Nig Creek** area from Yoho Resources Ltd. in early 2014. So far, Storm has drilled 18 horizontal wells in the Upper Montney at Umbach with 14 wells producing. Storm continues to modify its horizontal drilling techniques to improve average 30 day, 90 day and first-year production rates as displayed by a comparison of operating days shown in Table 2. The company estimates that the most recent horizontal wells (10–14) will average 2.4 mmcf/d in the first year with an ultimate recovery of 4.4 Bcf. Activity in 2014 will include drilling 14 horizontal wells and the completion and tie-in of 13 wells. A 24 mmcf/d compressor station will be built with a start-up date in September 2014.

Painted Pony Petroleum Ltd. is one of the most active producers in the northwest section of the Montney play trend and is well positioned to be a key supplier to British Columbia's proposed west coast LNG export terminals. The producer continues to delineate and develop its large-scale and conveniently located natural gas assets in the northern Montney region. The company's Montney rights now extend over 52 500 ha (203 net sections) with a 74% average working interest. These interest areas include the **Cypress**, **Blair Creek**, **Daiber** and **Town** areas (NTS 094B/15 and 094B/16) and the more recently purchased assets in the **Townsend–Kobes** area (NTS 094B/09). Painted Pony's 2014 net capital budget forecast of $169 million is earmarked for its Montney project (Painted Pony Petroleum Ltd., 2014) and includes finishing construction on a 25 mmcf/d compression and dehydration facility in the Blair Creek area and the expansion of a Daiber-area dry gas facility from 25 to 50 mmcf/d. Forty-two operated wells have been drilled since 2005 in the Montney project, which targets three productive Triassic Montney Formation intervals (Upper, Lower and Middle). Painted Pony refers to these intervals as "three stacked resource plays in one" with the Montney exploitable gas column being more than 300 m thick, gas charged and highly overpressured. In the first quarter of 2014, production from the Montney project reached approximately 53 mmcfe/d and 8800 BOE/d of liquids. The liquids content in the project area averages approximately 13 barrels/mmcf of recoverable C^{2+}. Painted Pony's development program activities in 2014 are estimated to generate an average production rate of 13 500 BOE/d; this is expected to grow to an average of 35 500 BOE/d by 2016. The company plans to drill 15 wells in its Montney project in 2014. From January to April 2014, six wells were drilled; all were located in the Town area. In Painted Pony's recently acquired interests in the Townsend–Kobes area, production began on two horizontal wells on the company's a-11-J/94-B-09 pad. The first Montney well targeted liquids-rich gas from the Upper Montney interval and represents the first time that the Upper Montney has been targeted in this area. The second well targeted the Lower Montney interval. The two wells have been producing since March 2013 with aggregate (combined) cumulative gas reaching 1.28 Bcf and 13 427 barrels of condensate in February 2014. The second well was completed using the recently adopted open-hole ball-drop packer-style system rather than perf-and-plug technology. The ball-drop packer-style technology offers an increase in the number of completion stages per well (typically 17–19 stages, as opposed to 8–10 stages using the perf-and-plug style). More recently, Painted Pony has achieved considerable early production gains from the implementation of a paired parallel-well drilling and completion pattern. This advancement combines operational experience using open-hole fracture stimulations with new sequencing and refined placement of Montney horizontal well trajectories (Nickle's Daily Oil Bulletin, 2014d).

Black Swan Energy Ltd., a private equity–backed exploration and production company formed in 2010, will continue its delineation program in the **Beg and Aitken Creek** areas of the northern Montney play trend in 2014. Black Swan holds approximately 58 000 ha (144 000 acres) in the region, which offers

TABLE 2. STORM RESOURCES' COMPARISON OF HORIZONTAL WELL DAY RATES IN THE UMBACH AREA OF NORTHEAST BRITISH COLUMBIA. ABBREVIATIONS: HZ, HORIZONTAL; MMCF, MILLION CUBIC FEET; WI, WORKING INTEREST.

Range of horizontal wells	Working interest	Area	Start of production	Frac stages	30 operating days average mmcf/d	90 operating days average mmcf/d	360 operating days average mmcf/d
Hz 1–5	60% WI	Umbach North	Mar/11 – Oct/12	7 to 11	2.7 Mmcf/d 5 hz	2.1 Mmcf/d 5 hz	1.4 Mmcf/d 5 hz
Hz 6–9	60% WI	Umbach North	Nov/12 – Aug/13	14 to 16	3.3 Mmcf/d 3 hz	2.8 Mmcf/d 3 hz	not available
Hz 10–14	100% WI	Umbach South	Apr/13 – Nov/13	17 to 18	4.2 Mmcf/d 5 hz	3.7 Mmcf/d 3 hz	not available

a reasonably low-cost opportunity in a thick, gas-charged resource within the overpressured region of the northern Montney (Black Swan Energy Ltd., 2014). Black Swan drilled its first Montney well in the Beg area in March 2012 at b-A79-G/94-G-01. As of February 2014, the well is producing at a calendar day rate of 902 mcf/d with cumulative production of 746 mmcf. Activity in 2013 included six development and two outpost wells drilled in the area. One of Black Swan's most productive wells drilled to date was rig released in the Beg area in mid-August 2012 (c-088-A/94-G-1). Since December 2013, it has recorded production from the Triassic Montney of 312 mmcf at a calendar day rate of 3.7 mmcf/d and cumulative condensate production of 4037 barrels.

Canbriam Energy Inc. continues to see promising results from its **Altares/Farrell Creek** Montney project. Canbriam operates approximately 95 sections (24 500 ha) in this west-central region of the Montney fairway. The producer estimates an OGIP of 38 Tcf on its lands with the potential for more than 1500 net locations (Canbriam Energy Inc., 2014). The company's growth strategy during the next four years is designed to increase production in the area to three or four times the current 10 000 BOE/d (80% gas). At year-end 2013, proved plus probable reserves from the project area were 519 Bcf of gas and 23.3 million barrels of liquids. Canbriam will continue to focus on these area lands due to their prospectivity for natural gas liquids, which yield approximately 50 barrels/mmcf on nearly 50% of Canbriam's land. Canbriam's drilling activity in 2013 was exclusively centered in the Altares area (NTS 094B/08), where eight wells were drilled. In the first four months of 2014, four wells have been drilled; again, all within Canbriam's Altares property.

Murphy Oil Corporation was an early participant in the development of Triassic shale gas potential from the Montney turbidites in the **Tupper Creek** area (Tupper West, Tupper Main). The producer recently deferred development at Tupper Main and Tupper West to focus on managing netbacks. For example, Murphy has signed third-party processing agreements to process up to 60 mmcf/d at Tupper. It also plans to optimize well completions to fill existing plant capacity and lower overall unit operating expenses (Murphy Oil Corporation, 2014). Murphy rig released only four wells in 2013 with all wells drilled in the **Sundown** and **Swan Lake** areas. In early 2014, the company was operating two rigs at Sundown with plans to bring 25 wells on line during the remainder of the year. Murphy will implement a new completion strategy and a downhole choke management plan at Tupper West and Tupper Main. These techniques are based on similar practices used in the Eagle Ford Shale where EURs have shown improvement in offset wells. Gas production from Murphy's Montney operations is expected to fall by 15%, from 170 mmcf/d in 2013 to 145 mmcf/d in 2014.

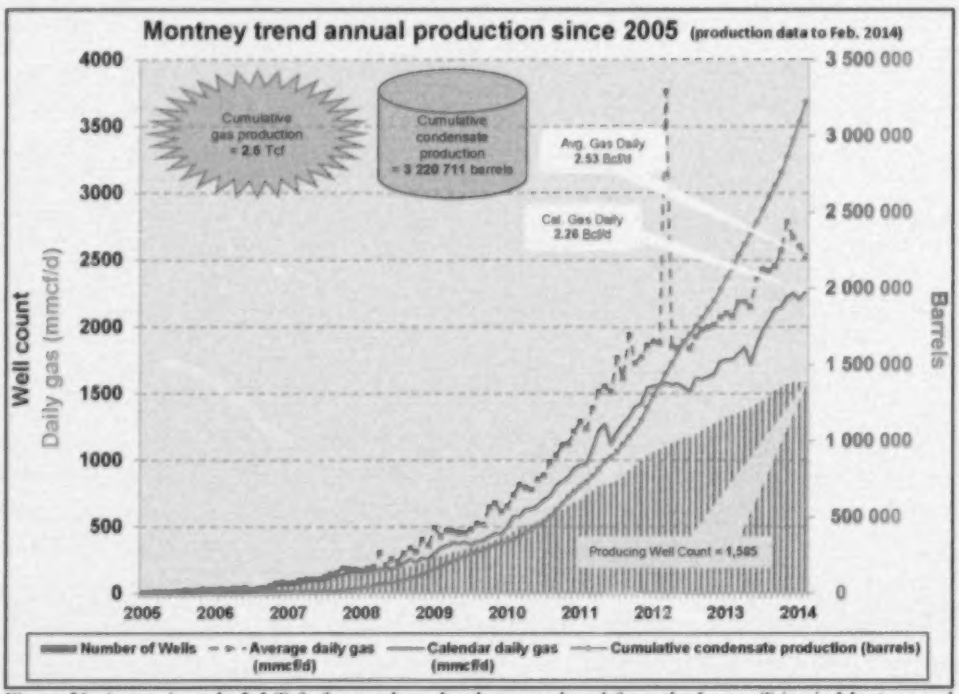


Figure 21. Approximately 2.5 Tcf of natural gas has been produced from the Lower Triassic Montney and Doig Phosphate formations from 2005 to February 2014. The average daily calendar rate in February 2014 was 2.26 Bcf/d from 1585 producing wells. Cumulative condensate production to the end of February 2014 was 3 220 711 barrels. Abbreviations: avg, average; Bcf, billion cubic feet; cal, calendar; cum, cumulative; cnd, condensate; dly, daily; mmcf, million cubic feet; nbr, number; prd, production.

Production

Continuing improvement in horizontal drilling and completion techniques have resulted in significant production from areas within the Montney play trend. The application of these techniques and the added value of liquids-rich gas production have been the key components to unlocking the economic potential of the region. Gas production from the Montney and Doig phosphate formations within the play trend has increased considerably since 2005 with the average calendar daily rate reaching 2.3 Bcf/d from 1585 producing wells at the end of February 2014 (Fig. 21). The play region has seen cumulative gas production of approximately 2.5 Tcf.

Cretaceous Shale Gas Activity (Fort St. John and Northern Foothills Regions)

Shale gas activity directed towards Cretaceous horizons in Northeast British Columbia continues to be assessed in several areas of the Fort St. John and Northern Foothills resource regions. Lower Cretaceous sequences are the focus of exploration in the Beg–Jedney areas and further south in the Blair and Farrell creek areas. Each of these areas has unique characteristics in terms of shale gas potential. Companies currently operating in these areas are evaluating fracture stimulation programs and continue to optimize completion methods that could result in increased well productivity. In Northeast British Columbia, the Buckinghorse Formation is approximately 1000 m thick and extends in a northwesterly direction in a broad, low-lying belt along the eastern edge of the Foothills between the Halfway and Muskwa rivers (Glass, 1997).

Industry Activity

Painted Pony Petroleum Ltd. has amassed approximately 41 440 net ha (160 net sections) of prospective Lower Cretaceous Buckinghorse rights in the greater **Blair Creek** area. The producer has been experimenting with drilling and completion techniques during the last four years and feels that there is an 800 m thick section in the area that is suitable for vertical development of 16 to 32 wells per section (Painted Pony Petroleum Ltd, 2014). So far, three wells have been production tested at Blair Creek. A hydraulic fracturing program is planned for two existing wells in the area in 2014. Painted Pony also believes the Buckinghorse shale could have potential further north of Blair Creek in the **Julienne Creek** area and to the south in the **Cameron** area.

As of December 2013, **UGR Blair Creek Ltd.** (UGR) held more than 22 000 net ha of land interest in the unconventional Montney play trend. Within that interest, UGR has additional upside potential in the untapped shales of the Lower Cretaceous Buckinghorse. In May 2009, UGR was granted special project approval by the OGC for two experimental schemes in the **Town** area within the Montney play trend. The purpose of the schemes was to test the commercial viability of shale gas potential in the Lower Cretaceous Fort St. John Group. One of UGR's wells in the **Blair Creek** area (well authorization 13846 at b-87-G/94-B-16) began production from the Lower Cretaceous Shaftesbury Formation in December 2008 with an initial average daily rate of 283 mcf/d. The latest production data available are from October 2011, when the well was producing at an average rate of 83 mcf/d and cumulative production had reached 19.7 mmcf. UGR's net resource in place for the Buckinghorse shale is 25 Tcfe (Unconventional Gas Resources, 2014).

OUTLOOK

Unconventional resource play development continues to thrive in many areas of Northeast British Columbia. Although industry is steadily challenged with the demand and price fluctuations of world commodity markets, the increasing knowledge of British Columbia's unconventional gas regions through resource play development and new recovery techniques is a key factor influencing the pace of industry activity. Capital spending on exploration and development activities in the province has been reasonably sound since 2005. The latest figures from the Canadian Association of Petroleum Producers (CAPP) in 2013 indicate capital spending of $5.7 billion, not far off from a capital spending record in 2008 of $7.9 billion. According to the British Columbia Ministry of Natural Gas Development's 2014/15–2016/17 Service Plan, annual investment in natural gas and oil exploration is forecast at $5.5 billion in 2013/14, which is approximately 10% more than the $4.8 billion 2013/14 target provided in the 2013/14–2015/16 Ministry Service Plan. The increase is primarily the result of higher-than-expected activity in the Montney play region as producers continue to develop the liquids-rich areas (British Columbia Ministry of Natural Gas Development, 2014).

Going forward, investment in natural gas exploration and development activities is critical to an emerging LNG export industry in British Columbia. As an oil and gas jurisdiction, Northeast British Columbia continues to offer a clear competitive advantage in terms of unconventional development and production. Raw natural gas production in British Columbia in 2013 was 1.58 Tcf (4.4 Bcf/d), which was second highest in Canada or 26% of total Canadian production. Raw gas production from British Columbia's shale gas regions now contributes more than 60% of the province's total gas production, and that percentage continues to grow. Natural gas producers continue to introduce new technology to unlock the vast potential of unconventional gas resources in Northeast British Columbia. Innovative oil and gas royalty programs and continuing geoscience research will

also have a noteworthy impact on British Columbia's unconventional gas industry and the export of LNG to overseas markets.

ACKNOWLEDGMENTS

The author thanks Talitha Castillo for her assistance in preparing many of the maps contained in this report. This report has benefited greatly from editorial reviews by Purple Rock Inc. and Fil Ferri.

REFERENCES

Adams, C. (2011): Summary of shale gas activity in northeast British Columbia 2011; *British Columbia Ministry of Natural Gas Development*, Oil and Gas Reports 2012-01, 18 pages.

Adams, C. (2013): Summary of shale gas activity in northeast British Columbia 2012; *British Columbia Ministry of Natural Gas Development*, Oil and Gas Reports 2013-01, 27 pages.

Apache Corporation (2014a): Fourth quarter, year-end 2013 update; *Apache Corporation*, URL <http://www.apachecorp.com/Operations/Canada/Kitimat_Project/Horn_River_and_Liard_basins/index.aspx> [February 2013].

Apache Corporation (2014b): 2013 4th quarter & full-year earnings release operations supplement; *Apache Corporation*, URL <http://www.apachecorp.com/Resources/Upload/file/investors/Apache_4QYE13_Operations_Supplement_20140213.pdf> [March 2014].

ARC Resources Ltd. (2014a): Operations – NE British Columbia; *ARC Resources Ltd.*, URL <http://www.arcresources.com/operations/ne-british-columbia/> [April 2014].

ARC Resources Ltd. (2014b): ARC Resources a clear line of sight; Howard Weil Energy Conference, March 25, 2014; *ARC Resources Ltd.*, URL <http://www.arcresources.com/investors/presentations-and-events/presentations-and-webcasts/> [April 2014].

ARC Resources Ltd. (2014c): News release, February 5, 2014 – ARC Resources Ltd. reports fourth quarter and year end 2013 results; *ARC Resources Ltd.*, URL <http://www.arcresources.com/investors/reporting/financial-reports/> [April 2014].

Artek Exploration Ltd. (2014a): Artek Exploration Ltd. announces 2014 capital program with continued focus on liquids and value growth; *Artek Exploration Ltd.*, URL <http://artekexploration.com/doc/pr/Artek14PR-Feb11.pdf> [February 2014].

Artek Exploration Ltd. (2014b): Artek Exploration Ltd. provides operational update Calgary, Alberta – January 28, 2014; *Artek Exploration Ltd.*, URL <http://artekexploration.com/doc/pr/Artek14PR-Jan07.pdf> [February 2014].

Artek Exploration Ltd. (2014c): Artek Exploration Ltd. balance, impact, upside, shareholder value January 2014; *Artek Exploration Ltd.*, URL <http://artekexploration.com/doc/pr/ArtekJan2014present.pdf> [February 2014].

Asia Pacific Foundation of Canada (2010): STX Energy of South Korea acquires gas field in BC; *Asia Pacific Foundation of Canada.*, URL <http://www.asiapacific.ca/news/stx-energy-south-korea-acquires-gas-field-bc> [March 2014].

British Columbia Oil and Gas Commission (2012): Montney formation play atlas; *British Columbia Oil and Gas Commission*, URL <http://www.bcogc.ca/publications/Reports> [November 2013].

British Columbia Oil and Gas Commission (2013): Hydrocarbon and by-product reserves in British Columbia 2012; *British Columbia Oil and Gas Commission*, URL <http://www.bcogc.ca/publications/Reports> [December 2013].

British Columbia Oil and Gas Commission (2014a): Horn River Basin unconventional activity report (2013/14 Q3); *British Columbia Oil and Gas Commission*, URL <https://files.bcogc.ca> [March 2014].

Black Swan Energy Ltd. (2014): Corporate Presentation June 2014; *Black Swan Energy Ltd.*, URL <http://www.blackswanenergy.com / News-and-Presentations/index.php> [June 2014].

British Columbia Ministry of Natural Gas Development and National Energy Board (2011): Ultimate potential for unconventional natural gas in northeastern British Columbia's Horn River Basin; *Energy Market Assessment*, Oil and Gas Reports 2011-1, 39 pages.

British Columbia Ministry of Natural Gas Development (2014): 2014/15–2016/17 Service Plan; *British Columbia Ministry of Natural Gas Development and Minister Responsible for Housing*, URL <http://www.bcbudget.gov.bc.ca/2013_June_Update/serviceplans.htm> [February 2014].

British Columbia Newsroom (2013): Fortune Creek gas plant granted conditional environmental assessment approval; *British Columbia Ministry of Environment*, URL <http://www.newsroom.gov.bc.ca/2013/10/fortune-creek-gas-plant-granted-conditional-environ mental-assessment-approval.html> [October 2013].

Canadian Natural Resources Ltd. (2014): Canadian Natural Resources Limited announces 2013 third quarter results; *Canadian Natural Resources Ltd.*, URL <http://www.cnrl.com/ upload/media_element/683/01Aq313_interim-report.pdf> [May 2013].

Canbriam Energy Inc. (2014): Canbriam June 2014 presentation; *Canbriam Energy Inc.*, URL <http://www.canbriam.com/wp-content/uploads/2014/06/Canbriam_Presentation_June2014.pdf> [February 2013].

Crew Energy Inc. (2014): Corporate presentation June 2014; *Crew Energy Inc.*, URL <http://crewenergy.com/pdfs/crew_presentation.pdf> [June 2014].

Devon Energy Corporation (2012): Bank of America Merrill Lynch 2012 Global Energy Conference; *Devon Canada Corporation*, URL <http://www.devonenergy.com/ Documents/111312%20BOA%20Laptop.pdf > [January 2014].

Dobek, R. (1976): Well history report on Chevron North Helmet d-06-B/94-P-10; *British Columbia Oil and Gas Commission*, Well File 3679.

Encana Corporation (2013): Corporate presentation March 2013; *Encana Corporation*, URL <http://www.encana.com/investors/presentations-events/> [March 2013].

Encana Corporation (2014): Corporate Presentation June 2014; *Encana Corporation*, URL <http://www.encana.

com/pdf/investors/presentations-events/corporate-presentation.pdf > [April 2013].

Ferri, F., McMechan, M., Fraser, T., Fiess, K., Pyle, L. and Cordey F. (2013): Summary of field activities in the western Liard Basin, British Columbia; *in* Geoscience Reports 2013, *British Columbia Ministry of Natural Gas Development*, pages 13–31.

Ferri, F. and Griffiths M. (2014): Thermal maturity and regional distribution of the Muskwa Formation, northeastern British Columbia; *in* Geoscience Reports 2014, *British Columbia Ministry of Natural Gas Development*, pages 37–45.

Glass, D. J., Editor (1997): Lexicon of Canadian Stratigraphy, Volume 4, Western Canada, including Eastern British Columbia, Alberta, Saskatchewan and Southern Manitoba; *Canadian Society of Petroleum Geologists*, 1422 pages.

Imperial Oil Limited (2014): Imperial Oil announces estimated fourth quarter financial and operating results; *Imperial Oil Ltd.*, URL <http://www.imperialoil.com/Canada-English/Files/Earnings_Release_Q4_2013.pdf> [February 2014].

Janicki, E. (2008): Petroleum exploration history of northeastern British Columbia; *in* Geoscience Reports 2008, *British Columbia Ministry of Natural Gas Development*, pages 41–57.

Murphy Oil Corporation (2014): Murphy announces preliminary first quarter 2014 earnings; *Murphy Oil Corporation*, URL <http://ir.murphyoilcorp.com/phoenix.zhtml?c=61237&p=irol-newsArticle&ID=1924578&highlight=> [February 2014].

National Energy Board (2013): Aurora Liquefied Natural Gas Ltd. application for licence to export liquefied natural gas; *National Energy Board*, URL <http://www.neb-one.gc.ca/clf-nsi/rthnb/pplctnsbfrthnb/lngxprtlcncpplctns/lngxprtlcncpplctns-eng.html> [December 2013].

Nickle's Daily Oil Bulletin (2013a): Canadian conventional assets up for sale, says Devon; *Nickle's Daily Oil Bulletin*, URL <http://www.dailyoilbulletin.com/article/2013/11/27/jvs-wont-impede-sale-of-peace-river-cordova-assets/> [November 2013].

Nickle's Daily Oil Bulletin (2013b): JVs won't impede sale of Peace River, Cordova assets, Penn West says; *Nickle's Daily Oil Bulletin*, URL <http://www.dailyoilbulletin.com/ article/2013/11/7/canadian-conventional-assets-up-for-sale-says/> [November 2013].

Nickle's Daily Oil Bulletin (2014a): Quicksilver's proposed Fortune Creek gas plant receives environmental approval; *Nickle's Daily Oil Bulletin*, URL <http://www.dailyoilbulletin.com/article/2013/10/11/quicksilvers-proposed-fortune-creek-gas-plant/> [February 2014].

Nickle's Daily Oil Bulletin (2014b): After running about 28 rigs for much of the winter, PETRONAS proves it's serious about western Canada; *Nickle's Daily Oil Bulletin*, URL <http://www.dailyoilbulletin.com/article/2014/ 4/9/after-running-about-28-rigs-much-winter-petronas-p/> [April 2014].

Nickle's Daily Oil Bulletin (2014c): Canadian Natural hikes budget, considers royalties sale, reports stronger quarter; *Nickle's Daily Oil Bulletin*, URL <http://www.dailyoilbulletin.com/article/2014/5/9/canadian-natural-hikes-budget-considers-royalties-/> [May 2014].

Nickle's Daily Oil Bulletin (2014d): Painted Pony adds $31 million to 2014 capex program; releases Q1 results; *Nickle's Daily Oil Bulletin*, URL <http://www.dailyoilbulletin.com/article/2014/5/14/painted-pony-adds-31-million-2014-capex-program-re/> [May 2014].

Paramount Resources Ltd. (2013): Corporate Presentation January 2013; *Paramount Resources Ltd.*, URL <http://www.paramountres.com/upload/quick_link/8/33/paramount-resources-ltd-january-2013-corporate-presentation-jim-riddell.pdf > [January 2013].

Paramount Resources Ltd. (2014): Annual Results 2013; *Paramount Resources Ltd.*, URL <http://www.paramountres.com/investor-relations/financial-reports#2013> [May 2013].

Painted Pony Petroleum Ltd. (2014): Corporate presentation May 15, 2014; *Painted Pony Petroleum Ltd.*, URL <http://paintedpony.ca/2014/corporate-presentation-may-15-2014/may-15-2014-fina/> [May 2014].

Penn West Exploration (2013): Third quarter results and long-term plan November 6, 2013; *Penn West Exploration Ltd.*, URL <http://www.pennwest.com/investors/presentations-webcasts> [December 2012].

Progress Energy Canada Ltd. (2013): TransCanada selected to develop $6 billion in natural gas infrastructure to Prince Rupert, British Columbia; *Progress Energy Canada Ltd.*, URL <http://www.progressenergy.com/news/2013-news-releases> [January 2013].

Progress Energy Canada Ltd. (2014a): Progress Energy Canada and Pacific Northwest LNG welcome third partner to British Columbia LNG export project; *Progress Energy Canada Ltd.*, URL <http://www.progressenergy.com/2014/03/07/progress-energy-canada-and-pacific-northwest-lng-welcome-third-partner-to-british-columbia-lng-export-project/> [April 2014].

Progress Energy Canada Ltd. (2014b): Progress Energy continues to build upon its leading Montney natural gas position with the completion of two acquisitions in northeast British Columbia; *Progress Energy Canada Ltd.*, URL <http://www.progressenergy.com/media-centre/news/archives/> [April 2014].

Quicksilver Resources Inc. (2014): December 2013 company presentation; *Quicksilver Resources Inc.*, URL <http://investors.qrinc.com/events.cfm> [February 2014].

Shell Canada Limited (2014a): Groundbirch; *Shell Canada Limited*, URL <http://www.shell.ca/en/aboutshell/our-business-tpkg/upstream/e-and-p-canada/groundbirch.html> [June 2014].

Shell Canada Limited (2014b): The Groundbirch Gazette, Fall 2013 issue; *Shell Canada Limited*, URL <http://www.shell.ca/en/aboutshell/our-business-tpkg/upstream/e-and-p-canada/groundbirch-montney.html> [April 2014].

Storm Resources Ltd. (2014a): February 2014 update; *Storm Resources Ltd.*, URL <http://www.stormresourcesltd.com/ presentations.php> [February 2014].

Storm Resources Ltd. (2014b): Operations Horn River Basin; *Storm Resources Ltd.*, URL <http://www.stormresourcesltd.com/horn-river-basin.php> [February 2014].

Storm Resources Ltd. (2014c): June 2014 update; *Storm Resources Ltd.*, URL <http://www.stormresourcesltd.com/documents/Storm%20Resources%20June%202014.pdf> [June 2014].

Talisman Energy Inc. (2013): Corporate presentation 2013; *Talisman Energy Inc.*, 24 pages.

Talisman Energy Inc. (2014a): Peters & Co. Limited 2013 North American oil and gas conference, September 12,

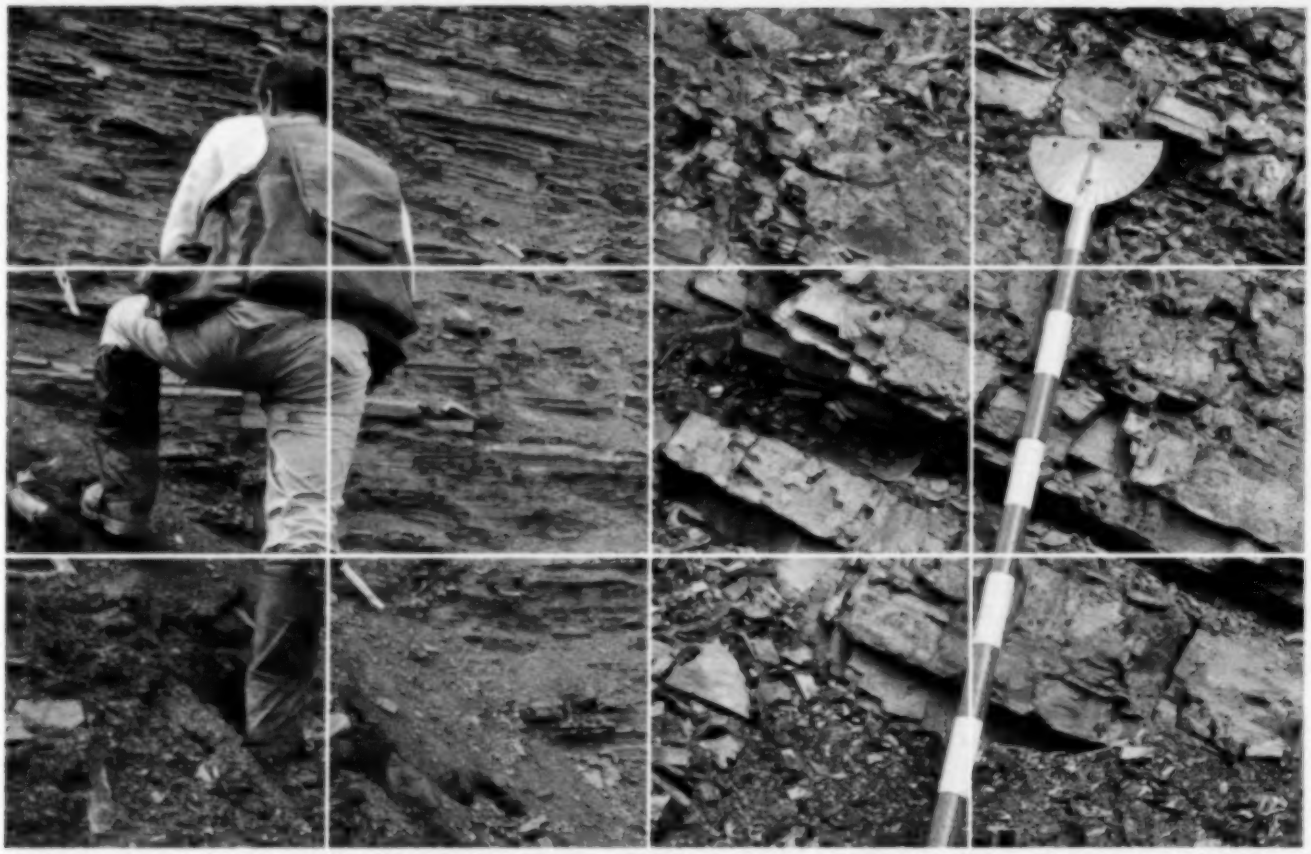
2013; *Talisman Energy Inc.*, URL <http://www.talisman-energy.com/investors/news_and_events/> [March 2014].

Talisman Energy Inc. (2014b): News releases–Talisman Energy Inc. completes C$1.5 billion Montney transaction; *Talisman Energy Inc.*, URL <http://talismanenergy.mwnewsroom.com/> [March 2014].

Tourmaline Oil Corp. (2014): Corporate presentation May 2014; *Tourmaline Oil Corporation*, URL <http://www.tourmalineoil.com/presentations/> [May 2014].

Transeuro Energy Corp. (2014): News release–strategic update March 28 2014; *Transeuro Energy Corp.*, URL <http://www.transeuroenergy.com/s/NewsReleases.asp?ReportID=644764&_Type=News-Releases&_Title=NEWS-RELEASE-STRATEGIC-UPDATE> [April 2014].

Unconventional Gas Resources (2014): British Columbia operations; *Unconventional Gas Resources*, URL <http://ugresources.com/operations/britishcolumbia,canada> [May 2014].



BRITISH COLUMBIA

Ministry of
Natural Gas Development

For more information, please contact:
Ministry of Natural Gas Development
Oil and Gas Division
Tenure and Geoscience Branch